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THE RELATIONS BETWEEN FREE-AIR TEMPERATURES AND WIND DIRECTIONS.*

By WILLIS RAY GREGG, Meteorologist.

[Weather Bureau, Washington, D. C., January, 1924.]

SYNOPSIS.

All available data from kite flights made during the period 1915 to 1922, inclusive, have been considered. The investigation has been pursued along the following lines: (1) The temperatures at different heights have been classified according to surface wind direction; (2) the temperatures at 3 kilometers have been classified according to wind direction at that level; and (3) changes in temperature at 3 kilometers, as observed during series of successive kite flights extending over periods of several hours, have been examined individually in connection with the wind direction or with changes in the wind direction. It is found (*a*) that in a large majority of cases the relation between temperatures and wind directions is direct and appreciable, south component winds being considerably warmer than north component winds at all levels in the troposphere; (*b*) that the relation is more pronounced at 1 and 2 kilometers than it is at greater heights or at the surface; and (*c*) that exceptions to (*a*) are due either to a temporary reversal in the latitudinal distribution of temperature or to the fact that the wind direction in some instances does not represent the true source of the air, the latter having followed a curved path round a HIGH or LOW.

INTRODUCTION.

The relation between free-air temperature and wind has in recent years been the subject of considerable discussion and some controversy. There are those who hold that the wind direction exercises practically no influence upon the temperature;[1] others, that the relation is the reverse of that at the surface, or in other words that a north-component wind is accompanied by rising temperature and vice versa;[2] and still others, that the normal and most frequent condition is a lower temperature with wind from a northerly than with wind from a southerly quarter, or, what amounts essentially to the same thing, as will be explained later, a lower temperature with rising than with falling barometric pressure.[3]

The purpose of the present paper is to bring to the discussion of this subject such additional information as is now available as the result of a large number of free-air observations made in the United States from 1915 up to the present time. The study has been pursued along the following lines: (1) The temperatures at different heights have been classified according to surface wind direction; (2) the temperatures at 3 kilometers have been classified according to wind direction at that level; and (3) changes in temperature at 3 kilometers, as observed during series of successive kite flights extending over periods of several hours, have been examined individually in connection with the wind direction or with changes in the wind direction.

1. FREE-AIR TEMPERATURES AND SURFACE WIND DIRECTIONS.

In this part of the study all observations made with kites at stations that have been in operation since 1915 have been considered, and the same general characteristics are apparent in all cases. However, the discussion is confined chiefly to data from Drexel, Nebr., and Ellendale, N. Dak., because of the greater length of record at those stations and therefore the greater dependability of the results. Table 1 contains the number of observations at selected levels for the 16 wind directions. There is about equal distribution among the 4 seasons. All directions are well represented except ENE. to ESE. in the higher levels. At the bottom of the table is given the number of observations with NNW. to NNE. and SSE. to SSW. winds, i. e., with distinctly north and south components, respectively.

TABLE 1.—*Number of observations on which are based the results given in Tables 2, 3, 4, and 6, and in Figure 2.*

Surface wind direction.	Altitude above M. S. L. (meters).									
	Drexel, Nebr.					Ellendale, N. Dak.				
	396	1,000	2,000	3,000	4,000	444	1,000	2,000	3,000	4,000
N	178	173	128	84	21	124	120	68	34	11
NNE	101	96	55	23	6	90	88	42	22	4
NE	101	94	60	30	10	61	57	24	10	3
ENE	65	61	36	17	4	45	42	23	10	1
E	61	59	36	19	3	28	25	16	7	3
ESE	68	65	36	19	5	47	45	31	14	3
SE	121	115	91	58	17	59	57	48	24	2
SSE	202	201	163	103	22	82	81	63	35	10
S	237	231	196	120	39	167	162	131	70	25
SSW	232	229	198	146	53	106	106	85	53	23
SW	134	132	122	92	28	43	43	36	22	4
WSW	84	80	68	55	21	39	39	35	25	12
W	75	74	67	52	14	76	75	69	44	14
WNW	74	74	64	46	15	85	82	75	49	18
NW	148	146	130	97	20	153	150	117	76	25
NNW	212	206	170	103	30	112	110	86	34	15
Total	2,093	2,036	1,620	1,064	308	1,317	1,282	949	529	173
NNW.-NNE	491	475	353	210	57	326	318	196	90	30
SSE.-SSW	671	661	557	369	114	355	349	279	158	58

Observed values of temperature at selected levels have been averaged for each surface wind direction and for each season and the year, and these averages have been smoothed by the well-known process $\frac{a+2b+c}{4}$, in which a, b, and c represent values corresponding to successive wind directions. The results are given in

[1] Dines, W. H.: The characteristics of the free atmosphere. *Geophysical Memoirs, No. 13.* Meteorological Office, London, 1919, p. 66.

[2] Clough, H. W.: The sequence of the interdiurnal changes in wind direction, pressure and temperature in the free air. Abstract in *Bulletin of the American Meteorological Society,* 1922, p. 114.

[3] Blair, Wm. R.: Free-air data. Sounding balloon accensions at Indianapolis, Omaha, and Huron. *Bulletin of the Mount Weather Observatory.* Vol. 4, pt. 4, pp. 192-193. 1912.

Meisinger, C. LeRoy: The preparation and significance of free-air-pressure maps for the central and eastern United States. MO. WEATHER REV. SUPPLEMENT No. 21, pp. 19-20. 1922.

Gregg, W. R.: Vertical temperature distribution in the lowest 5 kilometers of cyclones and anticyclones. MO. WEATHER REV., September, 1919. 47: 647-649.

* Presented before American Meteorological Society at Cincinnati, Ohio, Dec. 29, 1923, and Philosophical Society of Washington, Feb. 23, 1924.

Table 2. Highest and lowest temperatures at each level are indicated by bold face and italic type respectively, and the difference between these values is given at the bottom of each section of the table.

TABLE 2.—*Mean temperatures, (°C.), at various heights corresponding to surface wind direction.*

SPRING.

Surface wind direction.	Altitude above M. S. L. (meters).									
	Drexel, Nebr.					Ellendale, N. Dak.				
	396	1,000	2,000	3,000	4,000	444	1,000	2,000	3,000	4,000
N	*6.2*	*1.9*	−1.1	−5.7	*−11.4*	1.7	−1.2	−3.9	−8.4	−13.6
NNE	6.5	2.4	−0.4	−5.1	−10.6	3.2	0.5	−2.0	−6.0	−11.1
NE	7.6	3.7	0.8	−4.0	−9.2	5.4	3.1	0.2	−3.5	−8.3
ENE	8.3	5.0	2.2	−2.6	−8.5	7.4	4.9	1.0	−3.2	−7.2
E	8.7	5.8	3.4	−1.8	−9.5	9.7	6.8	2.0	−4.1	−7.0
ESE	9.6	7.0	4.0	−1.3	−9.6	9.7	6.8	2.5	−4.6	−6.9
SE	10.8	8.3	4.6	−0.8	−8.5	9.2	6.2	2.4	−3.5	−6.8
SSE	12.5	10.0	5.7	−0.1	−7.4	9.4	6.8	2.8	−2.2	−7.0
S	13.8	11.0	6.4	0.4	−6.4	8.8	7.4	2.8	−2.7	−8.3
SSW	14.0	11.1	6.1	0.0	−6.4	7.4	7.4	2.3	−3.8	−10.4
SW	12.8	10.3	4.7	−1.7	−7.8	6.5	6.9	1.8	−4.4	−11.6
WSW	11.0	9.0	3.1	−3.4	−9.4	7.3	6.5	0.7	−6.1	−12.5
W	10.4	7.4	1.7	−4.5	−10.0	8.3	5.8	−0.8	−7.8	−13.6
WNW	8.6	4.4	−0.8	−6.6	−11.0	5.3	2.2	−3.6	−9.8	−15.2
NW	6.7	2.4	*−1.9*	*−7.2*	−11.2	1.4	*−1.8*	*−6.0*	*−11.1*	*−16.3*
NNW	*6.2*	2.0	−1.5	−6.2	−11.1	*1.3*	*−1.8*	−5.2	−9.9	−15.2
Max.-Min	7.8	9.2	8.3	7.6	5.0	8.4	9.2	8.8	8.9	9.5

SUMMER.

Surface wind direction.	396	1,000	2,000	3,000	4,000	444	1,000	2,000	3,000	4,000
N	21.0	16.9	11.9	6.5	0.6	18.7	*14.9*	10.5	5.4	0.2
NNE	*20.8*	17.1	12.2	6.5	0.8	18.3	15.3	11.5	6.6	2.0
NE	21.4	17.8	13.2	7.4	1.2	*18.0*	15.8	11.5	6.8	2.2
ENE	21.7	18.2	13.8	7.9	0.8	*18.0*	16.0	11.4	6.8	1.3
E	21.4	18.4	13.8	7.3	−0.9	19.4	16.8	11.6	7.1	0.7
ESE	21.5	18.9	14.0	7.6	−1.0	21.3	18.0	12.6	7.6	0.8
SE	22.4	19.8	14.5	8.0	0.3	22.6	19.0	13.8	8.4	1.4
SSE	23.7	20.8	14.9	8.2	1.1	22.9	19.8	14.7	8.8	1.6
S	25.0	21.8	15.6	8.6	1.7	22.6	20.3	14.8	7.8	0.4
SSW	25.6	22.6	16.1	8.6	1.6	21.7	20.2	14.2	6.4	−1.4
SW	25.2	22.6	16.2	8.4	1.0	20.1	19.3	13.2	5.5	*−1.8*
WSW	24.2	22.2	15.8	8.3	0.5	19.3	18.0	12.0	4.8	−1.3
W	22.9	20.7	14.1	7.1	−0.2	19.2	16.8	10.3	4.1	−1.2
WNW	21.4	18.3	11.5	4.8	−1.4	19.4	16.2	9.5	3.8	−1.4
NW	20.9	*16.8*	*10.0*	*3.8*	*−2.0*	19.5	15.7	*9.4*	*3.7*	−1.3
NNW	21.4	16.9	10.9	5.2	−0.8	19.2	15.0	*9.4*	4.1	−1.2
Max.-Min	4.8	5.8	6.2	4.8	3.7	4.9	5.4	5.4	5.1	3.4

AUTUMN.

Surface wind direction.	396	1,000	2,000	3,000	4,000	444	1,000	2,000	3,000	4,000
N	6.2	3.5	0.8	−3.9	−8.8	*1.5*	0.1	−1.7	−6.0	−11.6
NNE	7.5	5.3	2.7	−2.8	−8.4	4.4	3.5	1.7	−2.4	−8.1
NE	10.1	8.4	5.4	0.2	−5.9	8.3	7.1	4.5	−0.2	−7.0
ENE	12.1	11.2	7.3	2.2	−3.4	9.4	8.5	5.3	0.0	−8.2
E	12.3	11.7	7.8	1.8	−2.0	7.6	7.4	4.7	−1.4	−9.3
ESE	13.8	12.4	8.8	2.6	−1.4	7.0	6.1	4.6	−1.6	−8.3
SE	15.4	13.6	9.9	3.7	−2.1	8.6	7.3	6.1	0.6	−6.4
SSE	15.2	13.9	10.2	3.8	−2.9	9.8	9.7	7.8	2.0	−5.1
S	14.8	13.6	10.0	3.9	−2.8	8.3	9.8	6.9	1.0	−5.5
SSW	13.3	12.6	8.6	2.8	−3.2	7.0	8.6	4.7	−1.5	−7.1
SW	12.0	11.7	6.8	0.8	−4.6	7.8	8.4	3.5	−3.1	−7.8
WSW	11.9	11.6	5.7	−0.7	−6.0	8.1	8.0	2.8	−3.4	−7.8
W	10.2	9.2	3.6	−2.6	−7.2	8.1	7.0	2.0	−3.7	−8.8
WNW	7.6	5.6	1.3	−4.1	−8.9	6.8	4.6	0.1	−5.2	−11.1
NW	6.3	3.4	0.0	*−4.8*	*−9.8*	4.1	1.4	−2.4	−7.5	−13.4
NNW	*5.8*	*2.6*	*−0.3*	−4.6	−9.3	1.6	*−0.7*	*−3.5*	*−8.4*	*−14.0*
Max.-Min	9.6	11.3	10.5	8.5	8.4	8.3	10.5	11.3	10.4	8.9

WINTER.

Surface wind direction.	396	1,000	2,000	3,000	4,000	444	1,000	2,000	3,000	4,000
N	−7.7	−8.9	−7.6	−11.2	−17.3	−11.7	−10.8	−9.6	−13.1	−18.1
NNE	−7.0	−7.2	−5.8	−9.0	−16.3	*−12.8*	−11.0	−8.8	−12.2	−16.6
NE	−7.3	−7.0	−5.8	−9.3	−15.0	−11.1	−9.5	−8.0	−10.8	−16.1
ENE	−5.9	−4.9	−4.4	−8.7	−12.5	−7.6	−6.2	−6.2	−8.8	−15.6
E	−3.2	−1.0	−1.8	−6.6	−11.2	−7.1	−5.4	−4.0	−8.0	−15.1
ESE	−2.5	0.0	−1.5	−6.2	−11.8	−8.1	−6.8	−3.0	−8.0	−14.8
SE	−3.2	−0.8	−1.7	−6.1	−11.4	−8.0	−7.6	−3.1	−8.0	−14.5
SSE	−3.5	−1.2	−1.0	−5.6	−10.7	−7.9	−6.3	−3.1	−8.2	−14.3
S	−3.0	−0.3	0.0	−5.0	−10.2	−8.6	−3.6	−3.4	−9.0	−14.6
SSW	−1.6	2.3	1.0	−4.2	−9.7	−7.7	−1.5	−3.6	−9.6	−15.3
SW	−0.5	3.7	0.7	−5.0	−10.5	−5.2	−0.3	−3.9	−10.2	−16.0
WSW	−0.4	2.7	−1.2	−6.9	−12.0	−4.4	−1.7	−5.9	−11.8	−17.5
W	−1.6	0.0	−3.7	−8.8	−14.2	−4.4	−3.8	−7.5	−13.0	−19.0
WNW	−4.0	−3.9	−6.6	−11.0	−16.5	−6.1	−6.6	−9.1	−14.3	−20.0
NW	−6.6	−7.7	−8.9	−12.9	−17.8	−9.8	−10.7	*−11.8*	*−16.4*	*−21.6*
NNW	*−8.1*	*−9.8*	*−9.6*	*−13.2*	*−18.1*	−11.3	*−11.6*	−11.6	−15.6	−20.8
Max.-Min	7.7	13.5	10.5	9.0	8.4	8.4	11.3	8.8	8.4	7.3

TABLE 2.—*Mean temperatures, (°C.), at various heights corresponding to surface wind direction*—Continued.

ANNUAL.

Surface wind direction.	Altitude above M. S. L. (meters).									
	Drexel, Nebr.					Ellendale, N. Dak.				
	396	1,000	2,000	3,000	4,000	444	1,000	2,000	3,000	4,000
N	6.4	3.4	1.0	−3.6	−9.2	*2.6*	0.8	−1.2	−5.5	−10.8
NNE	7.0	4.4	2.2	−2.6	−8.6	3.3	2.1	0.6	−3.5	−8.4
NE	8.0	5.7	3.4	−1.4	−7.5	5.2	4.1	2.0	−1.9	−7.3
ENE	9.0	7.4	4.7	−0.3	−5.9	6.8	5.8	2.9	−1.3	−7.4
E	9.8	8.7	5.8	0.2	−5.9	7.4	6.4	3.6	−1.6	−7.7
ESE	10.6	9.6	6.3	0.7	−6.0	7.5	6.0	4.2	−1.6	−7.3
SE	11.4	10.2	6.8	1.2	−5.4	8.1	6.2	4.8	−0.6	−6.6
SSE	12.0	10.9	7.4	1.6	−5.0	8.6	7.5	5.6	0.1	−6.2
S	12.6	11.5	8.0	2.0	−4.4	7.8	8.5	5.3	−0.7	−7.0
SSW	12.8	12.2	8.0	1.8	−4.4	7.1	8.7	4.4	−2.1	−8.6
SW	12.4	12.1	7.1	0.6	−5.5	7.3	8.6	3.6	−3.0	−9.3
WSW	11.7	11.4	5.8	−0.7	−6.7	7.6	7.7	2.4	−4.1	−9.8
W	10.5	9.3	3.9	−2.2	−7.9	7.8	6.4	1.0	−5.1	−10.6
WNW	8.4	6.1	1.4	−4.2	−9.4	6.4	4.1	−0.8	−6.4	−11.9
NW	6.8	3.7	*−0.2*	*−5.3*	*−10.2*	3.8	1.2	*−2.7*	*−7.8*	*−13.2*
NNW	*6.3*	*2.9*	−0.1	−4.7	−9.8	2.7	*0.2*	*−2.7*	−7.4	−12.8
Max.-Min	5.5	9.3	8.2	7.3	7.8	6.0	8.5	8.3	7.9	7.0

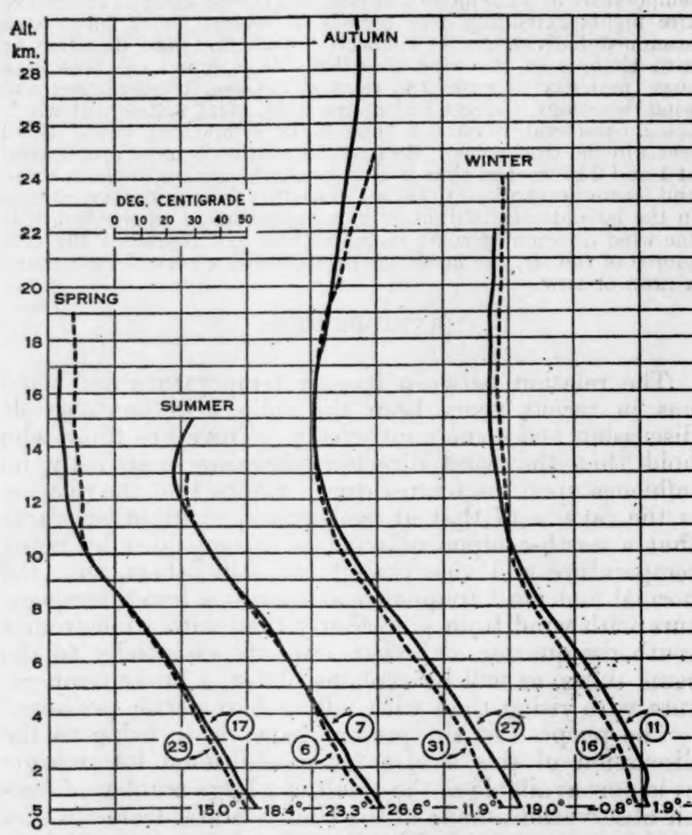

FIG. 1.—Mean temperatures over falling sea level air pressure (solid lines) and over rising sea level air pressure (broken lines); or, with south and north component winds, respectively. (Numbers in circles indicate number of observations upon which curves are based.)

A mere glance at the values in this table shows that at all levels up to at least 4 kilometers much higher temperatures prevail with south component than with north component surface winds. Essentially the same characteristics are apparent in the four seasons, viz, highest temperatures with SE. to SW. winds and lowest with NW. to N. winds. Differences are smallest in summer, averaging about 5° C.; in the other three seasons, among which there is little variation, they average 9° to 10°C. In all seasons they are greatest at 1 and 2 kilometers, but at 4 kilometers they are still sufficiently large, 7° to 8° C., to indicate a continuance of this relation to the upper limits of the troposphere. This conclusion finds

support in the results of a large number of sounding balloon observations made in this country. In discussing these, Blair [4] states that lower temperatures are found at all levels in the troposphere with rising than with falling air pressure at the surface, conditions which are accompanied by north-component and south-component winds, respectively. The reverse relation exists in the stratosphere in part because, as is well known, in this region there is an increase, instead of a decrease, in temperature with latitude; in part also because the warmer northward moving air, being the less dense of the two, would cause a vertical displacement of air in the stratosphere upward, a process that would result in more or less cooling of the latter. The curves showing these relations are based upon Figure 33 in Blair's paper and are here presented in Figure 1.

More detailed examination of the values in Table 2 brings out the fact that the change in temperatures from northerly to southerly winds is quite uniformly progressive. This is true for all seasons and for all stations. It is well shown in Figure 2, which gives the temperature distribution with surface wind direction at Drexel from the surface to the 4-kilometer level. It is interesting to note that at all heights the sharpest change occurs between SW. and NW. winds, temperatures accompanying W. winds being almost exactly halfway between these two in the upper levels. This large difference is presumably due in part to the greater average speed of these winds than of winds from other directions, but mostly to their greater steadiness or constancy of direction over long distances, thus enabling them to bring in air from considerably warmer or colder regions respectively. Instances are not infrequent, especially in winter, when a steady NW. or SW. wind prevails in the upper levels over a major portion of the country. Moreover, as will be explained later, these winds have a smaller deviation from the surface upward than do others, and form therefore what may be called a nearly "solid" current in a vertical as well as in a horizontal sense.

From Table 2 it is possible to compute the average lapse rates, °C. per 100 m., for the different directions. This has been done and the results are presented in Table 3, in 3 groups, viz, surface to 1,000 meters, 1,000 to 3,000 meters, and surface to 3,000 meters.

TABLE 3.—*Average temperature lapse rates (°C. per 100 m.), for different surface wind directions at Drexel, Nebr., and Ellendale, N. Dak.*

[Highest and lowest values indicated by bold face and italic type, respectively.]

SURFACE TO 1,000 METERS, M. S. L.

Surface wind direction.	Drexel, Nebr. Spring.	Summer.	Autumn.	Winter.	Annual.	Ellendale, N. Dak. Spring.	Summer.	Autumn.	Winter.	Annual.
N	**0.71**	0.68	0.45	0.20	0.50	0.52	0.68	0.25	−0.16	0.32
NNE	0.68	0.61	0.36	0.03	0.43	0.49	0.54	0.16	−0.32	0.22
NE	0.64	0.59	0.28	−0.05	0.38	0.41	0.40	0.22	−0.29	0.20
ENE	0.54	0.58	0.15	−0.17	0.26	0.45	0.36	0.16	−0.25	0.18
E	0.48	0.50	0.10	−0.36	0.08	0.52	0.47	0.04	−0.31	0.18
ESE	0.43	0.43	0.23	−0.41	0.17	0.52	0.59	0.16	−0.23	0.26
SE	0.41	0.40	0.30	−0.40	0.20	0.54	0.65	0.23	−0.07	0.34
SSE	0.41	0.48	0.21	−0.38	0.08	0.47	0.56	0.02	−0.29	0.20
S	0.46	0.53	0.20	−0.45	0.08	0.25	0.41	−0.26	−0.90	−0.13
SSW	0.48	0.50	0.12	−0.64	0.10	*0.00*	0.26	*−0.29*	*−1.12*	*−0.29*
SW	0.41	0.43	*0.05*	*−0.69*	*0.05*	0.07	*0.14*	−0.11	−0.88	−0.23
WSW	*0.33*	*0.33*	*0.05*	−0.51	*0.05*	0.14	0.23	0.02	−0.49	−0.02
W	0.50	0.36	0.17	−0.26	0.20	0.45	0.43	0.20	−0.11	0.25
WNW	0.69	0.51	0.33	−0.02	0.38	0.56	0.58	0.40	0.09	0.41
NW	**0.71**	0.68	0.48	0.08	0.51	**0.58**	0.68	**0.49**	**0.16**	**0.47**
NNW	0.69	**0.74**	**0.53**	**0.28**	**0.56**	0.56	**0.76**	0.41	0.05	0.45

[4] Blair, Wm. R.: Free-air data: Sounding balloon ascensions at Indianapolis, Omaha, and Huron. *Bulletin of the Mount Weather Observatory.* Vol. 4, pt. 4, pp. 192–193. 1912.

TABLE 3.—*Average temperature lapse rates (°C. per 100 m.), for different surface wind directions at Drexel, Nebr., and Ellendale, N. Dak.*—Continued.

1,000 METERS TO 3,000 METERS, M. S. L.

Surface wind direction.	Drexel, Nebr. Spring.	Summer.	Autumn.	Winter.	Annual.	Ellendale, N. Dak. Spring.	Summer.	Autumn.	Winter.	Annual.
N	0.38	0.52	0.37	0.12	0.35	0.36	0.48	0.30	0.12	0.32
NNE	0.38	0.53	0.40	*0.09*	*0.35*	*0.32*	*0.44*	*0.30*	0.06	*0.28*
NE	*0.38*	*0.52*	0.41	0.12	0.36	0.33	0.45	0.36	0.06	0.30
ENE	0.38	0.52	0.45	0.19	0.38	0.40	0.46	0.42	0.13	0.36
E	0.38	0.56	0.50	0.28	0.42	0.54	0.48	0.44	0.13	0.40
ESE	0.42	0.56	0.49	0.31	0.44	0.57	0.52	0.38	0.06	0.38
SE	0.46	0.59	0.49	0.26	0.45	0.48	0.53	0.34	*0.02*	0.34
SSE	0.50	0.63	0.50	0.22	0.46	0.45	0.55	0.38	0.10	0.37
S	0.53	0.66	0.48	0.24	0.48	0.50	0.62	0.44	0.27	0.46
SSW	0.56	0.70	0.49	0.32	0.52	0.56	**0.69**	0.50	0.40	0.54
SW	0.60	**0.71**	0.54	0.44	0.58	0.56	**0.69**	**0.58**	**0.50**	0.58
WSW	**0.62**	0.70	**0.62**	**0.48**	**0.60**	0.63	0.66	0.57	**0.50**	**0.59**
W	0.60	0.68	0.59	0.44	0.58	**0.68**	0.64	0.54	0.46	0.58
WNW	0.55	0.68	0.48	0.36	0.52	0.60	0.62	0.49	0.38	0.52
NW	0.48	0.65	0.41	0.26	0.45	0.64	0.60	0.44	0.28	0.45
NNW	0.41	0.58	*0.36*	0.17	0.38	0.58	0.54	0.38	0.20	0.38

SURFACE TO 3,000 METERS, M. S. L.

Surface wind direction.	Drexel, Nebr. Spring.	Summer.	Autumn.	Winter.	Annual.	Ellendale, N. Dak. Spring.	Summer.	Autumn.	Winter.	Annual.
N	0.46	0.56	0.39	0.13	0.38	0.40	0.52	0.29	0.05	0.32
NNE	0.45	0.55	0.40	*0.08*	0.37	0.36	0.46	*0.27*	*−0.02*	*0.27*
NE	0.45	0.54	*0.38*	*0.08*	0.36	*0.35*	*0.44*	0.33	−0.01	0.28
ENE	0.42	*0.53*	*0.38*	0.11	*0.36*	0.41	*0.44*	0.37	0.05	0.32
E	*0.40*	0.54	0.40	0.13	0.37	0.54	0.48	0.35	0.04	0.35
ESE	0.42	0.53	0.43	0.14	0.38	0.56	0.54	0.34	0.00	0.36
SE	0.45	0.55	0.45	0.11	0.39	0.50	0.56	0.31	0.00	0.36
SSE	0.48	0.59	0.44	0.08	0.40	0.45	0.55	0.30	0.01	0.33
S	0.54	0.63	0.42	0.08	0.41	0.45	0.58	0.29	0.02	0.33
SSW	0.54	0.65	0.40	0.10	0.42	0.44	0.60	0.33	0.07	0.36
SW	0.56	0.64	0.43	0.17	0.45	0.43	0.57	0.43	0.20	0.40
WSW	0.55	0.61	0.48	0.25	0.48	0.52	0.57	0.45	0.29	0.46
W	0.57	0.61	**0.49**	**0.28**	**0.49**	**0.63**	0.59	0.46	**0.34**	**0.50**
WNW	**0.58**	0.64	0.45	0.27	0.48	0.59	0.61	**0.47**	0.32	0.50
NW	0.53	**0.66**	0.43	0.24	0.46	0.49	**0.62**	0.45	0.26	0.45
NNW	0.48	0.62	0.40	0.20	0.42	0.44	0.59	0.39	0.17	0.40

The first two sections of this table indicate a very nearly opposite relation of lapse rate to wind direction in the lower and in the higher levels. From the surface to 1,000 meters, M. S. L. (about 600 meters actually, the station altitudes being, Drexel 396 and Ellendale 444), lapse rates are lowest with SSW. to WSW. and highest with NW. and NNW. winds; from 1,000 to 3,000 meters they are *highest* with SW. and WSW., and *lowest* with N. to NE. winds.

Southerly winds are of course cooled at the surface as they move to higher latitudes; this cooling produces a stable condition of the air and therefore does not extend to the upper levels. Northerly winds, on the other hand, are warmed at the surface in their progress toward lower latitudes, and this warming *does* extend to the upper levels, in diminished degree of course, since it tends to a condition of instability and therefore convectional activity sets in.

This characteristic difference in temperature lapse rates accompanying northerly and southerly winds is reflected in the decrease of relative humidity from the surface to the 1,000-meter level. As is well known, surface southwesterly winds in general are least humid, and northeasterly most humid.[5] The values in Table 4 show that this difference extends to the upper levels, at any rate to 4 kilometers. Only the annual values for Drexel are given, as those for Ellendale and for all seasons at both stations are essentially the same as these so far as distribution with wind direction is concerned. The last column of the table contains the average decrease in relative humidity from the surface to the 1,000-meter level. From these figures it is seen that the largest

[5] See figs. 24 and 25 in conjunction with figs. 8 and 10 in *A statistical study of surface and upper-air conditions in cyclones and anticyclones passing over Davenport, Iowa,* by A. D. Udden. MO. WEATHER REV. February, 1923, 51: 58 and 61.

decrease occurs with SW. and WSW. winds and the smallest with N. and NNW. winds. As already stated, air going northward is cooled at the surface. As a result of this cooling the relative humidity rises, but that in the upper levels suffers no change. Hence, the large decrease in the first 500 meters or so. Air going southward, on the other hand, is warmed at the surface, but this warming and the resulting decrease in relative humidity are propagated upward by convectional activity, so that there is a fairly even distribution at all levels.

TABLE 4.—*Average annual relative humidities for different surface wind directions at Drexel, Nebr.; also, average decrease from surface to 1,000 m.*

[Highest and lowest values indicated by bold face and italic type, respectively.]

Surface wind direction.	Altitude above M. S. L. (meters).					Decrease, surface to 1,000 meters.
	396	1,000	2,000	3,000	4,000	
N	73	**70**	60	58	59	*3*
NNE	74	69	**62**	62	66	5
NE	74	68	**62**	65	68	6
ENE	**75**	67	**62**	65	69	8
E	**75**	66	**62**	**66**	**70**	9
ESE	74	65	61	64	65	9
SE	72	63	58	59	59	9
SSE	69	61	59	56	57	8
S	68	57	52	53	53	11
SSW	65	52	48	49	48	13
SW	*64*	*48*	*45*	*47*	48	**16**
WSW	*64*	*48*	47	48	50	**16**
W	66	53	50	50	48	13
WNW	66	58	53	49	*44*	8
NW	69	64	55	51	46	5
NNW	72	69	57	54	52	*3*

The second section of Table 3 indicates the characteristic lapse rates in the air above the direct influence of surface warming or cooling. By reference to Table 4 it will be seen that the driest winds, SW. and WSW., have the largest lapse rates, and the wettest winds, NNE. to E. those with which precipitation most frequently occurs, have the smallest lapse rates. The differences give striking testimony to the effect of latent heat of condensation upon vertical temperature distribution. This effect is most pronounced, or at any rate of most frequent occurrence, in the lower layers of the atmosphere, from about 500 to 3,000 meters above the surface, where condensation is most active. At higher levels the lapse rate is more nearly constant regardless of wind direction. Evidence of this approach to the same value is to be found in Table 2. Owing to the small number of observations at 4 kilometers with easterly surface winds, only the general features can be considered significant, but these show mean annual lapse rates between 3 and 4 kilometers varying from about 0.55 with northerly winds to about 0.65 with southerly winds at both Drexel and Ellendale. These lapse rates increase to about 0.65 and 0.70, respectively, at still greater heights, thus approaching but never quite reaching the same value. This approach to a constant lapse rate is presumably due to vertical movement of the air, upward in southerly, downward in northerly winds and attendant changes in humidity, condensation in the former, evaporation in the latter. The final result is lower temperature and greater height of the stratosphere above southerly than above northerly surface winds. Figure 1 shows this relation very satisfactorily.

Thus far we have considered the relations between free-air temperatures and wind directions at the surface. The contention may be made that a north or south component at the surface *does not necessarily mean* a north or south component, respectively, in the upper levels. This is correct: Observations show that in some instances a north component wind at the surface turns into a south component wind in the free air and vice versa, but they also show that in the great majority of cases the component that is dominant at the surface persists at all levels. The results of a detailed analysis of the data have been presented in Tables 18a to 19c, inclusive, of "An Aerological Survey of the United States."[6] and need therefore be only briefly referred to here. Excluding the E. and W. surface directions and combining the remaining directions into groups, we find the following percentage frequencies of north and south components at 3 and 4 kilometers:

TABLE 5.—*Average annual percentage frequencies of north and south components at 3 and 4 kilometers.*

Surface wind directions.	North component at—		South component at—	
	3 Kilometers.	4 Kilometers	3 Kilometers.	4 Kilometers.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
WNW.-ENE	89	89	....	....
NW.-NE	92	89	....	....
NNW.-NNE	94	90	....	....
ESE.-WSW	....	....	81	76
SE.-SW	....	....	85	77
SSE.-SSW	....	....	89	82

It is not surprising to find higher values with north than with south component winds. The normal turning with altitude is clockwise, except in the case of NW. to NE. winds which more frequently turn counterclockwise. However, they rarely back beyond a westerly direction. ENE. winds tend to a clockwise turning but this direction rarely occurs and therefore the total number of north component winds that change with altitude to a south component is comparatively small. Southerly surface winds, on the other hand, veer in a majority of cases, the frequency and amount of the turning being greatest with ESE. and least with WSW. winds. ESE. to SSW. winds seldom turn into a westerly direction, but those from SW. and WSW. have a north component at 3 and 4 kilometers in about 50 per cent of the cases. However, the deviation is usually small and the mean direction at 3 and 4 kilometers is almost exactly west, whereas the mean direction of surface WNW. and NW. winds at these levels is some 20° to 30° north of west. It thus appears that, even though the SW. and WSW. surface winds have a north component at the upper levels in about half the cases, their mean direction is nevertheless from a point considerably farther south than is that of the WNW. and NW. surface winds.

If we exclude these and consider only the NNW.-NNE. and SSE.-SSW. surface winds, we find from Table 5 that the percentage frequency of N. and S. components is 94 and 89, respectively, at 3 kilometers, and 90 and 82 at 4 kilometers. From Table 2 we can compute the mean annual temperatures for these direction groups. The figures follow:

TABLE 6.—*Mean annual temperatures (°C.), at various heights corresponding to winds having definite north and south components.*

Surface wind direction.	Altitude above M. S. L. (meters).									
	Drexel, Nebr.					Ellendale, N. Dak.				
	396	1,000	2,000	3,000	4,000	444	1,000	2,000	3,000	4,000
NNW.-NNE	6.2	3.6	1.0	−3.6	−9.2	2.9	1.0	−1.1	−5.5	−10.7
SSE.-SSW	12.5	11.5	7.8	1.8	−4.6	7.8	8.2	5.1	−1.0	−7.3

[6] MO. WEATHER REV. SUPPLEMENT NO. 20, 1922.

The extent to which a north or south component prevails at heights above 4 kilometers is not known. An examination of pilot-balloon observations indicates that winds with a north component at the surface have the same component at 8 to 10 kilometers in a majority of cases, but that those with a south component at the surface have a north component at these levels more frequently than a south component. As a rule, however, this north component is small, so that the mean direction is still several degrees nearer south than is that of the north-component group. In addition it may be remarked that pilot-balloon observations at these great heights can be made only under conditions of exceptional visibility and light wind velocity—those usually found during anticyclonic weather, when, as is well known, the upper pressure distribution is such as to produce west-northwesterly winds. Because of cloudiness and vigorous air movement cyclonic weather is ruled out, so far as investigation by pilot balloons at great heights is concerned. And it is in LOWS, particularly in the central and eastern parts, that we have reason to believe a south component in the upper levels prevails. Occasional observations of upper clouds confirm this view. It seems reasonable, therefore, to conclude with Hildebrandsson [7] as a result of exhaustive studies of cloud data that "there is a slow exchange of air along the meridians, caused by continuous cyclonic and anticyclonic whirls in the Temperate Zones. Indeed each of these whirls carries air on the one side from south to north and on the other from north to south." If this conclusion is well founded, it follows that, as indicated in figure 1, the relation between wind direction and temperature, although less pronounced, is nevertheless operative in the upper levels as well as in the lower.

2. FREE-AIR TEMPERATURES AND FREE-AIR WIND DIRECTIONS.

In order to set at rest any uncertainty as to the conclusiveness of the results discussed in the previous section, based as they are upon the assumption (quite definitely established, however), that a north or south component persists on the average at all levels, we shall here consider the relation in a more direct way, comparing the temperatures at 3 kilometers with the wind directions *actually observed at that level*. All observations made with kites during the summer, June, July, and August, and during the winter, December, January, and February, from 1915 to 1922, inclusive, have been used. The two transition seasons, spring and autumn, have not been included, since the seasonal changes themselves tend to mask those due to any other influences. Inasmuch as certain wind directions, particularly N. through E. to S., are rarely observed at 3 kilometers, some of the directions have been combined into groups, in order that the averages may be based upon a considerable number of observations. Thus, for Drexel and Ellendale, the directions ESE. to SSW. and NNW. to ENE. are grouped; SW., WSW., W., WNW., and NW. are given individually. E. is not included, as there were only 2 or 3 observations with that direction, and it could not of course be combined with other directions, since it has neither a north nor a south component. For the 5 stations other than Drexel and Ellendale the total number of observations is too small to warrant a more detailed grouping than ESE. to WSW., W. and WNW. to ENE. The results in detail for Drexel and Ellendale are presented in Table 7, and the more general results for all stations in Table 8, the number of observations being given in all cases, and the stations being arranged in order of latitude, beginning at the north.

[7] Results of some empiric researches as to the general movements of the atmosphere. Translation by W. W. Reed. MO. WEATHER REV., June, 1919. 47: 389.

TABLE 7.—*Mean temperatures (°C.), for different wind directions at 3 kilometers.*

[No.=number of observations, given in italics; T=temperature in °C.]

SUMMER.

Stations.	Wind directions.													
	ESE.-SSW.		SW.		WSW.		W.		WNW.		NW.		NNW.-ENE.	
	No.	T.	No.	T.	No.	T.	No.	T.	No.	T.	No.	T.	No.	T.
Ellendale, N. Dak...	*37*	8.8	*16*	10.1	*23*	8.1	*24*	6.3	*23*	4.2	*27*	6.4	*19*	3.4
Drexel, Nebr.....	*67*	8.9	*49*	10.6	*27*	9.6	*28*	8.0	*40*	6.5	*38*	5.6	*26*	5.1
	WINTER.													
Ellendale, N. Dak...	*5*	−5.8	*11*	−7.1	*19*	−10.9	*36*	−12.7	*39*	−13.1	*43*	−13.4	*17*	−14.9
Drexel, Nebr.....	*22*	−5.8	*21*	−4.6	*40*	− 5.7	*79*	− 7.2	*82*	−10.7	*68*	− 9.9	*29*	−13.6

The values in this table show that, without exception, temperatures accompanying south component winds are on the average higher than those with north component winds.

TABLE 8.—*Mean temperatures (°C.), for south component winds, ESE.-WSW., west winds, and north component winds WNW.-ENE.*

[No.=number of observations, given in italics; T=temperature in °C.]

Stations.	Wind directions.											
	Summer.						Winter.					
	ESE.-WSW.		W.		WNW.-ENE.		ESE.-WSW.		W.		WNW.-ENE.	
	No.	T.	No.	T.	No.	T.	No.	T.	No.	T.	No.	T.
Ellendale, N. Dak.....	*76*	8.9	*24*	6.3	*93*	5.2	*35*	−8.9	*36*	−12.7	*135*	−13.4
Drexel, Nebr..........	*143*	9.6	*28*	8.0	*104*	6.0	*89*	−5.4	*79*	− 7.2	*179*	−10.9
Royal Center, Ind.....	*32*	8.1	*17*	7.1	*28*	6.1	*29*	−6.8	*20*	− 8.8	*27*	− 8.9
Broken Arrow, Okla...	*61*	9.2	*7*	10.9	*11*	8.7	*23*	−1.0	*7*	− 0.7	*24*	− 6.4
Due West, S. C........	*7*	9.4	*11*	6.3	*9*	7.3	*9*	1.2	*5*	− 0.4	*16*	− 4.4
Leesburg, Ga..........	*9*	8.1	*1*	7.2	*1*	7.6	*8*	3.4	*5*	− 1.3	*14*	− 0.1
Groesbeck, Tex.......	*58*	9.7	*1*	8.6	*14*	8.2	*71*	3.6	*20*	1.8	*39*	− 1.7

As indicated in this table, the mean temperatures with south component winds are higher at all stations and in both seasons than are those with north component winds. Contrasts are greatest in winter, when a strong latitudinal temperature gradient prevails. In general west winds are accompanied by temperatures between those with north and south component winds. The exceptions appear to be due to the small number of observations upon which the means are based.

A point not brought out in the table is the small percentage of cases in which south component winds are accompanied by temperatures lower than the *mean* temperature with north component winds, and vice versa. Table 9 contains this information for Drexel and Ellendale.

TABLE 9.—*Percentage of cases in which temperature with south or north component winds is lower or higher than the mean temperature with north or south component winds, respectively.*

Stations.	South component.		North component.	
	Summer.	Winter.	Summer.	Winter.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ellendale, N. Dak.	17	23	12	21
Drexel, Nebr.	7	18	26	20

In considering the figures given in Table 8 the question naturally arises as to the height to which this difference in temperatures with north and south component winds extends. No direct answer can be given to this question, but it is significant to note that the difference is greater at 3 kilometers than it is at the surface, as shown in Table 10, in which the surface values are taken from Table 2 and those at 3 kilometers from Table 8.

TABLE 10.—*Comparison of mean temperatures with north and south component winds at the surface and at 3 kilometers.*

DREXEL, NEBR.

Level.	Summer.			Winter.		
	ESE.-WSW.	WNW.-ENE.	Dif.	ESE.-WSW.	WNW.-ENE.	Dif.
Surface	23.9	21.2	2.7	−2.1	−6.7	4.6
3 kilometer	9.6	6.0	3.6	−5.4	−10.9	5.5

ELLENDALE, N. DAK.

Level.	ESE.-WSW.	WNW.-ENE.	Dif.	ESE.-WSW.	WNW.-ENE.	Dif.
Surface	21.5	18.7	2.8	−7.1	−10.1	3.0
3 kilometer	8.9	5.2	3.7	−8.9	−13.4	4.5

It is somewhat surprising to find a greater difference at 3 kilometers than at the surface, but it should not be inferred from this that the difference increases still further at greater heights. As pointed out in the first section of this paper and as indicated in Figure 2, the contrast is greater at 1 to 2 kilometers than it is either below or above.[8] On the other hand it is evident, from Figure 1, that the relation between temperature and wind, though it probably diminishes at heights above 3 kilometers, is nevertheless direct and appreciable to the upper limit of the troposphere.

PROGRESSIVE CHANGES IN FREE-AIR TEMPERATURES ACCOMPANYING STEADY NORTH AND SOUTH COMPONENT WINDS OR CHANGES FROM ONE COMPONENT TO THE OTHER.

Thus far in this paper we have dealt with data from individual observations that are more or less independent of one another, without regard to the time element. It will now be interesting to investigate the changes in temperature that take place during short periods of time with different wind directions. In general kite flights are made once daily. These observations are hardly suited to the present purpose, since they do not show irregular changes that may have occurred during the intervening 24 hours, but fortunately there is available a large number of series of successive flights continuing over periods of 24 to 36 hours, the average length of each flight being in the neighborhood of 3 to 4 hours. In these flights a height of 3 kilometers is reached with sufficient regularity to warrant the use of that level as a basis for the study. At this height surface influences are largely eliminated, and diurnal influences also, since it has been found that the diurnal variation at heights above 2 kilometers is less than 1° C.

Successive flights are made most successfully under conditions of winds moderate in strength and fairly steady in direction. A change to strong or to particularly light winds, or a decided change in wind direction usually means an interruption to the series or its abandonment. Hence we have a large number of observations with winds having a steady north or south component, but comparatively few with a change from north to south component, and vice versa. Even of the latter, however, there are some 70 cases, enough to provide material for a rather conclusive discussion.

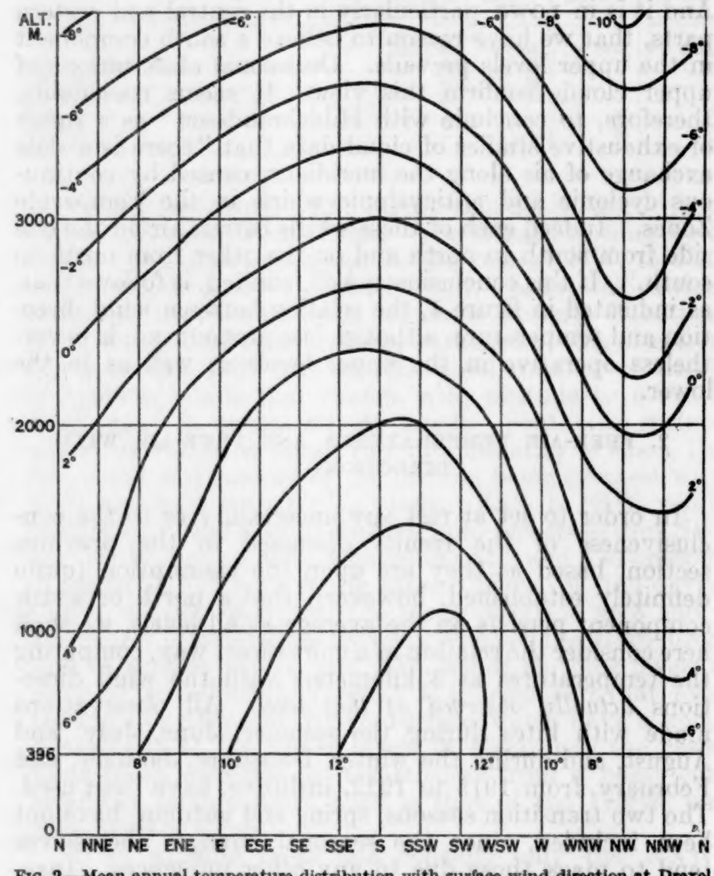

FIG. 2.—Mean annual temperature distribution with surface wind direction at Drexel from the surface to the 4-kilometer level.

An examination of all the data leads to the conclusion that the relations between progressive changes in temperature and wind direction are more pronounced in winter than in summer and at northern than at southern stations. The stations have therefore been considered in two groups—the northern group comprising Drexel, Ellendale, and Royal Center, and the southern, Broken Arrow, Groesbeck, Due West, and Leesburg. Table 11 contains for these two groups and for the seasons as well as the year the percentage frequency of increasing, decreasing, and no change in temperature accompanying winds with north and south components, and winds changing from one component to the other. "No change" in temperature represents a change so small, 1° C. or less, as to be within the limits of observational or instrumental errors.

[8] Cf. Meisinger, C. LeRoy: Preliminary steps in the making of free-air pressure and wind charts. Mo. WEATHER REV., May, 1920, 48: 251-263. In conclusion 1 on p. 262 he says: "* * * while wind direction produces a more marked effect upon temperatures aloft than at the surface." In this study conditions in the lowest 2 kilometers only were considered.

TABLE 11.—*Percentage frequency of increasing, decreasing, and no change in temperature at 3 kilometers accompanying winds with north and south components and winds changing from one component to the other.*

[Number of observations in italics.]

Stations.	North.				South.				North changing to south.				South changing to north.			
	Temperature change.															
	No.	+	−	0	No.	+	−	0	No.	+	−	0	No.	+	−	0
SPRING.																
Northern.....	*25*	28	40	32	*30*	67	20	13	*10*	100	0	0	*5*	20	60	20
Southern.....	*8*	37	63	0	*20*	60	15	25	*3*	100	0	0	*1*	0	100	0
Combined....	*33*	30	46	24	*50*	64	18	18	*13*	100	0	0	*6*	16	67	17
SUMMER.																
Northern.....	*17*	35	41	24	*50*	40	32	28	*4*	100	0	0	*4*	50	25	25
Southern.....	*2*	0	100	0	*24*	63	8	29	*0*	....	....	....	*2*	0	50	50
Combined....	*19*	32	47	21	*74*	47	24	29	*4*	100	0	0	*6*	33	34	33
AUTUMN.																
Northern.....	*40*	42	38	20	*45*	60	22	18	*5*	80	0	20	*11*	9	82	9
Southern.....	*12*	42	50	8	*26*	46	23	31	*1*	100	0	0	*1*	100	0	0
Combined....	*52*	42	41	17	*71*	55	22	23	*6*	83	0	17	*12*	17	75	8
WINTER.																
Northern.....	*39*	28	59	13	*17*	76	24	0	*15*	80	13	7	*5*	20	60	20
Southern.....	*14*	36	21	43	*13*	62	15	23	*4*	50	0	50	*3*	33	67	0
Combined....	*53*	30	49	21	*30*	70	20	10	*19*	74	10	16	*8*	25	63	12
ANNUAL.																
Northern.....	*121*	34	45	21	*142*	56	26	18	*34*	88	6	6	*25*	20	64	16
Southern.....	*36*	36	45	19	*83*	56	16	28	*8*	75	0	25	*7*	29	57	14
Combined....	*157*	35	45	20	*225*	56	22	22	*42*	86	5	9	*32*	22	62	16

Although in the majority of cases the normal relation between wind direction and temperature was found, i. e., falling temperature with north component winds and vice versa, especially with winds changing from one component to the other, yet the table shows that there were many exceptions. We shall now consider in more or less detail some of the individual series of observations, both types of relations being included. All of the 456 cases have been studied, but only a few can be given here. Those selected are not exceptional, but rather typical of the whole number.

DECREASING TEMPERATURES WITH NORTH COMPONENT WINDS.

As indicated in Table 11 there were 157 series of observations with north component winds. Of these 45 per cent showed decreasing temperatures. A few examples follow:

December 4–5, 1916, Table 12.—Weather conditions at Drexel during this series were controlled by a very active LOW which moved from north of Montana to Ontario. Pressure was relatively high, but with no well-defined center, in the Southern and Western States. Cooling was marked at all levels up to 4 kilometers and presumably much higher. The air that was brought in by the WNW. winds evidently originated far to the northward on the western side of the LOW.

TABLE 12.—*Drexel, Nebr., winds and temperatures at 3 kilometers, December 4–5, 1916.*

1916	Dec. 4.			Dec. 5.	
Time........	12 m.........	4 p. m........	12 midnight.	4 a. m.......	10 a. m.
Wind........	WNW.........	WNW.........	WNW.........	WNW.........	WNW.
Temp. °C.....	−0.6.........	−2.3.........	−7.3.........	−10.4.........	−10.6.

Surface wind, WNW. veering to NW. and later backing to W.; surface pressure rose 19 mb.

January 24–25, 1919, Table 13.—As indicated in Figures 3 and 4, there was a decided difference in pressure conditions on the two days during which this series of flights was made. On the 24th Ellendale was under the influence of an active LOW central north of Montana. During the next 24 hours this LOW diminished greatly in energy and moved eastward to Ontario. In the meantime high pressure, with no well defined center, spread over much of the Rocky Mountain and Great Plains regions. Free-air temperatures at Ellendale bore a close relation to this change in pressure distribution. While the LOW was dominant, upper winds brought in air that originated a considerable distance northward, as may be inferred from the isobars in Figure 3. By nightfall of the 24th the influence of this LOW was superceded by that of the western HIGH with its gently curving isobars. Thereafter little change in temperature occurred because the source of the air, even though the wind direction at Ellendale was still WNW., was evidently not to the north but rather to the west along the northern part of the HIGH, as can be seen by a glance at Figure 4. This HIGH was probably of greater vertical extent than normal for this season of the year, owing to the absence of any well-defined horizontal temperature gradient.

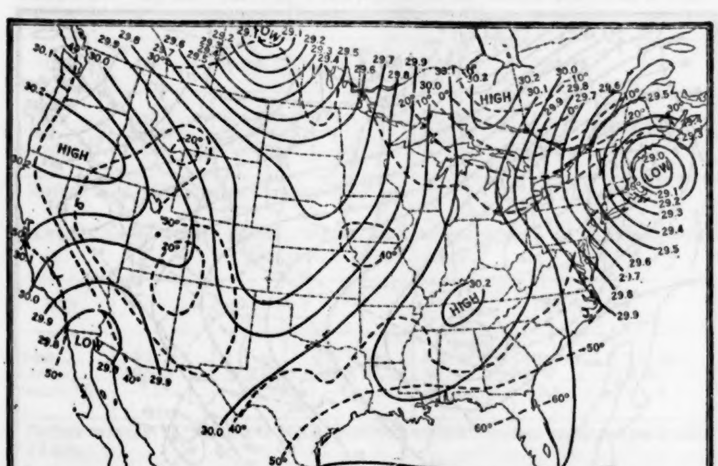

FIG. 3.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Jan. 24, 1919.

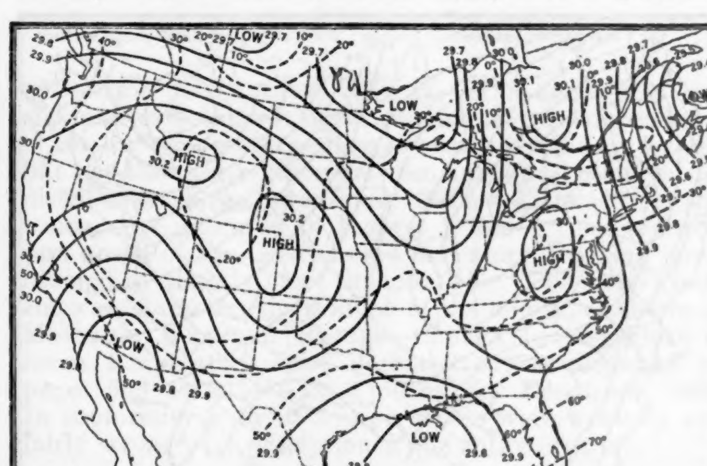

FIG. 4.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Jan. 25 1919.

This supposition is borne out by an observation at Drexel on the 25th, which showed a NNW. wind at 3 kilometers, essentially parallel to the sea-level isobars and a temperature only 2° C. higher than that at Ellendale as against a normal difference of 5° C. Presumably then the free-air isobars in the northern part of the HIGH were closely similar to those at sea level, and the source of the air supply at Ellendale was a considerable distance westward. It may be added as significant that on the following day, 26th, the free-air temperature had risen some 5 or 6° C., the wind direction still being WNW., which indicates that by this time air originating from the Pacific coast in the northwestern part of the HIGH was passing Ellendale. This seems reasonable from the fact that the speed of the free-air winds was about 50 m. p. h., or 1,200 miles per day—approximately the distance from Ellendale to the coast.

TABLE 13.—*Ellendale, N. Dak., winds and temperatures at 3 kilometers, January 24–25, 1919.*

1919	Jan. 24.				Jan. 25.		
Time	12 m.	3 p. m.	7 p. m.	10 p. m.	7 a. m.	11 a. m.	2 p. m.
Wind	WNW.	W.	WNW.	WNW.	NW.	WNW.	WNW.
Temp., °C.	−7.3	−11.4	−14.1	−14.0	−13.6	−13.8	−14.1.

Surface wind, NW. backing to SW., then veering to WNW., surface pressure rose 6 mb.

March 5–6, 1920, Table 14.—Pressure conditions were unusually active during these two days. On the morning of the 5th a well-developed LOW was central over eastern North Carolina; this moved to a position just off the New England coast during the next 24 hours. Meanwhile a HIGH of great magnitude advanced from central Alberta to Montana. There was a steep temperature as well as pressure gradient between these, the air in the upper levels at Leesburg coming from a long distance to the north. On the day following this series, 7th, the upper wind was still WNW. and a further cooling had occurred. Conditions at Royal Center, somewhat farther north, were closely similar to those at Leesburg. Free-air winds at 3 kilometers were continuously NW. from the 5th to 7th and during this period there was a fall in temperature from −15 to −23° C.

TABLE 14.—*Leesburg, Ga., winds and temperatures at 3 kilometers, March 5–6, 1920.*

1920	Mar. 5.			Mar. 6.		
Time	3 p. m.	7 p. m.	11 p. m.	3 a. m.	8 a. m.	1 p. m.
Wind	WNW.	WNW.	WNW.	WNW.	WNW.	WNW.
Temp., °C.	−2.4	−3.0	−3.6	−7.0	−9.7	−10.9.

Surface wind, NW; surface pressure rose 8 mb.

February 25–26, 1921, Table 15.—During this series a well-developed LOW moved from just north of the Dakotas southeastward to lower Lake Michigan. Of more importance, so far as free-air winds are concerned, was an area of intense cold between the upper Lakes and Hudson Bay. This produced in the upper levels an *eastward* shift of the LOW center from its sea level position, the reverse of normal; a steep pressure gradient northeastward from Drexel; and resulting strong NW. winds.

TABLE 15.—*Drexel, Nebr., winds and temperatures at 3 kilometers, February 25–26, 1921.*

1921	Feb. 25.			Feb. 26.	
Time	9 a. m.	1 p. m.	4 p. m.	2 a. m.	12 m.
Wind	WNW.	WNW.	WNW.	NW.	NNW.
Temp., °C.	−2.9	−1.0	−3.5	−8.9	−8.2.

Surface wind, SSW. veering to NNW.; surface pressure fell 12, then rose 14 mb.

Toward the end of the series a moderate HIGH developed over the central Rocky Mountain region and a LOW considerably farther north. It is evident that the free-air winds during the first day brought in air from the north, but on the second day from a more westerly quarter. This change is reflected in the small increase in temperatures from 2 a. m. to noon, Feb. 26, given in the table.

INCREASING TEMPERATURES WITH NORTH COMPONENT WINDS.

Fifty-four series of observations, or 35 per cent of all cases, showed increasing temperatures. This is a much larger proportion of exceptions than is found in any of the other three groups given in Table 11. It is thought well worth while, therefore, to give particular attention to some of the more conspicuous examples, most of which occurred at northern stations.

November 29–30, 1918, Table 16.—In two of the cases previously discussed there occurred a change in the source of the air supply from a northerly to a westerly point, with resulting temperature change, although the wind direction itself at the place of observation remained constant. In the series now under consideration this change in air source had proceeded yet further, as can be seen by a glance at the isobars in Figures 5 and 6. It is evident that the air flowing past Ellendale originated on the western side of the HIGH, some little distance off the coast. In this connection it may be

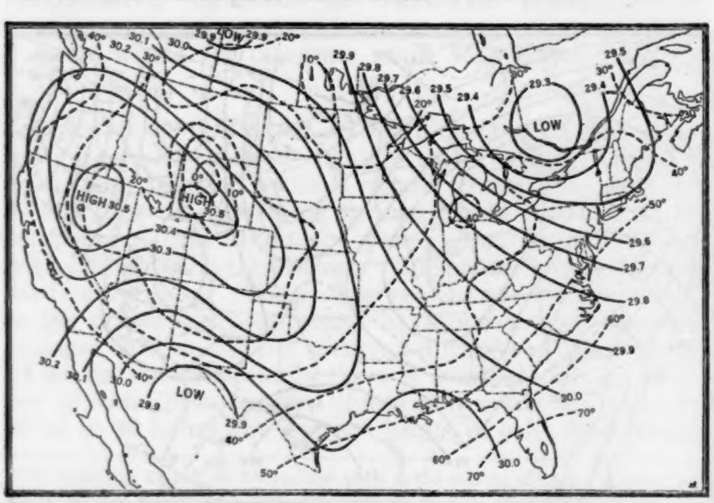

FIG. 5.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Nov. 29, 1918.

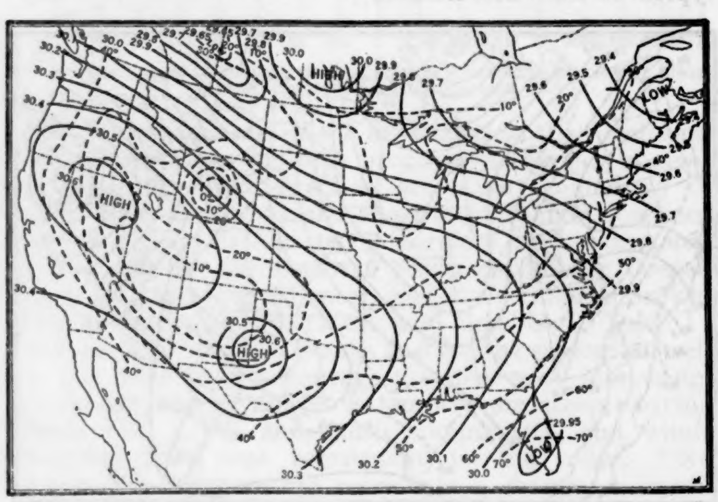

FIG. 6.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Nov. 30, 1918.

remarked that temperatures at all levels were lower on the 29th than on the 28th, when the HIGH extended considerably farther north and brought to Ellendale successively colder masses of air.

TABLE 16.—*Ellendale, N. Dak., winds and temperatures at 3 kilometers, November 29–30, 1918.*

1918	Nov. 29.				Nov. 30.				
Time....	10 a. m.	2 p. m.	6 p. m.	9 p. m.	1 a. m.	4 a. m.	7 a. m.	10 a. m.	1 p. m.
Wind...	WNW.	NW...	NW...	NW...	NW...	NW...	NW...	NNW..	NNW.
Temp., °C.....	−21.9	−18.8	−18.2	−17.4	−15.5	−13.8	−11.0	−10.0	−7.8

Surface wind, NW. backing to WSW., then veering to N.; surface pressure fell 7 mb.

Too much importance should not be attached to the higher temperatures on the west side of the northwestern LOW shown in Figures 5 and 6, than on its east side. As is well known, this is characteristic of North Pacific coast LOWS but in all probability is confined to low levels. Its principal effect, in conjunction with that of a reverse temperature distribution at higher levels, would be a greater tendency to symmetry with height, i. e., the absence of pronounced northwestward shift of the LOW center. In all probability the increasing temperatures at Ellendale were caused by warm air being brought from a southerly point round the northern side of the HIGH rather than by air at approximately the same latitude which was warm owing to the ocean's influence, for this latter is almost certainly in large part a surface phenomenon.

As indicated in the figures, Drexel was in the same general air stream as was Ellendale, upper winds on the 28th to 30th being northwesterly and the temperatures falling from the 28th to 29th and rising from the latter to the 30th.

December 15–17, 1919, Tables 17 and 18.—These two series are considered together, because they overlap each other as to time and because the conditions in the Far West during these three days were markedly uniform. An unusually well-developed and active HIGH was central over southern Idaho throughout this period. Not only was it stationery in position, but also practically constant as to intensity, varying but little from 30.8 inches at its center. There was a moderate LOW, also stationary for the most part, just north of Montana. Temperature contrasts were marked, there being low values in the main part of the HIGH, where clear weather prevailed and radiation was active, and high temperatures on all sides, those to the northeast being presumably the result of chinook action.

TABLE 17.—*Broken Arrow, Okla., winds and temperatures at 3 kilometers, December 15–16, 1919.*

1919	Dec. 15.			Dec. 16.		
Time.......	12 m.......	5 p. m.....	10 p. m.....	7 a. m.....	11 a. m.....	3 p. m.
Wind.......	WNW.....	WNW.....	W........	WNW.....	W.......	WNW.
Temp., °C..	−8.0.......	−8.0.......	−5.7.......	−4.6.......	−2.1.......	−1.4.

Surface wind, SSW.; surface pressure fell 7 mb.

TABLE 18.—*Drexel, Nebr., winds and temperatures at 3 kilometers, December 16–17, 1919.*

1919	Dec. 16.			Dec. 17.		
Time.......	10 a. m.....	2 p. m.....	10 p. m.....	5 a. m.....	10 a. m.....	2 p. m.
Wind.......	WNW.....	WNW.....	WNW.....	W.......	NW.......	NW.
Temp., °C..	−7.5.......	−8.4.......	−4.2.......	−5.0.......	−3.6.......	−1.4.

Surface wind, NW. veering to NNE. and later to SSE.; surface pressure rose 2, then fell 6 mb.

When this HIGH first came southward, it brought to the western part of the country a large mass of cold air, as indicated by observations at Ellendale, Drexel, and Broken Arrow where a decided decrease in temperatures occurred at all heights reached—3 to 4 kilometers. As soon, however, as the HIGH became stationary and an appropriate circulation was established, this cold air to the east was displaced by warmer air originating on the western side of the HIGH and flowing round its northern side. This condition was widespread, both horizontally and vertically, being apparent at the 3 stations above named and being almost as pronounced at 4 kilometers as near the surface, extending presumably therefore to the upper limit of the troposphere. At 3 kilometers pressure remained unchanged, the rise in temperature of the air column being offset by a fall in the surface pressure, as indicated in the tables.

January 9–10, 1920, Table 19.—As indicated in the table, the course of temperature change was not progressively in one direction, but consisted first of a rise and then of a fall. During this entire period pressure was again exceedingly high in the Plateau region, and it is significant to note that pressure was highest over southern Idaho on the 9th, but over Washington on the 10th, apparently due to mergence with another HIGH advancing from British Columbia. With this change there was apparently an alteration in the circulation, the air flowing past Drexel no longer coming from the Pacific Ocean round the northern part of the HIGH, but from the Canadian Northwest. This influence was of considerable duration, as revealed by an observation on the 11th, which showed a temperature of −17° C. at 3 kilometers, or a further drop of more than 5° C. It is worthy of remark also that on the day preceding this series, 8th, the HIGH, already well developed, was central over Washington and that the temperature at Drexel and 3 kilometers fell 4° C. during the next 24 hours. Thus, during the entire period, 8th to 11th, inclusive, there was intimate relation between the free-air temperature and the position of the HIGH, i. e., the source of the air supply.

TABLE 19.—*Drexel, Nebr., winds and temperatures at 3 kilometers, January 9–10, 1920.*

1920	Jan. 9.				Jan. 10.			
Time............	10 a. m.	2 p. m.	6 p. m.	9 p. m.	1 a. m.	5 a. m.	9 a. m.	2 p. m.
Wind............	W......	WNW.	WNW.	WNW.	WNW.	WNW.	WNW.	WNW.
Temp., °C.......	−16.1...	−13.8..	−10.2..	−8.4...	−9.1...	−9.1...	−10.2..	−11.4.

Surface wind, SSW. veering to NNW.; surface pressure fell 2, then rose 7 mb.

December 18–19, 1922, Table 20.—This series is of special interest because it illustrates not only the dependence of free-air temperatures upon the source of the air supply, but also the close relation between horizontal temperature distribution in the lower levels and free-air pressures and winds. As indicated in Figures 7 and 8, temperatures just north of the Great Lakes and along the Gulf coast differed by slightly more than 100° F. This steep gradient was characteristic of much of the month, as shown in MONTHLY WEATHER REVIEW Chart III, "departure of mean temperature from normal," and as discussed on pages 658 to 661 of that journal for December, 1922. In conformity with it, free-air winds were westerly and fairly strong over pretty much the entire country.

TABLE 20.—*Drexel, Nebr., winds and temperatures at 3 kilometers, December 18–19, 1922.*

1922	Dec. 18.				Dec. 19.	
Time	10 a. m.	2 p. m.	6 p. m.	11 p. m.	6 a. m.	10 a. m.
Wind	W.	WNW.	WNW.	WNW.	WNW.	W.
Temp., °C.	−12.0	−10.4	−11.4	−9.9	−6.1	−5.5.

Surface wind, SSW.; surface pressure fell 14 mb.

The increase in temperature with a north component wind at 3 kilometers appears in this case, as in others already cited, to be due to the air's having followed a curved path round the northern part of a practically stationary HIGH. In the present instance a vigorous LOW from the Pacific coast doubtless contributed; it is significant to note that the temperature rose decidedly although the surface pressure fell, a good example of the usual condition in this country, i. e., cyclones warmer than anticyclones. A similar warming occurred at Ellendale, but in this case the upper wind changed from WNW to W and WSW under the influence of the advancing LOW.

INCREASING TEMPERATURES WITH SOUTH COMPONENT WINDS.

Table 11 shows that 225 series of observations were made with the upper wind continuously from a southerly direction. In 56 per cent of these a rise in temperature occurred at 3 kilometers. Good examples of this relation between wind direction and temperature are found in 2 series of flights on March 30–31, 1920, one at Drexel and the other at Royal Center.

March 30–31, 1920, Tables 21 and 22.—During this period a moderate but well-developed HIGH was central over the Southeastern States and a very active LOW in the Northwest, the latter moving from slightly north of Montana to North Dakota, a comparatively short distance. The temperature gradient from north to south was about normal for this season of the year. Hence, winds from a southerly direction naturally brought to the different stations air that was progressively warmer. That this was a general condition over most of the country east of the Rockies is shown by observations at Ellendale, Broken Arrow, Groesbeck, and Leesburg, where free-air conditions prevailed similar to those at Drexel and Royal Center.

TABLE 21.—*Drexel, Nebr., winds and temperatures at 3 kilometers, March 30–31, 1920.*

1920	Mar. 30.				Mar. 31.	
Time	10 a. m.	2 p. m.	5 p. m.	9 p. m.	1 a. m.	12 m.
Wind	W.	WSW.	SW.	SW.	SW.	SW.
Temp., °C.	−4.9	−2.6	−3.5	−4.2	−1.0	0.4.

Surface wind, SW.; surface pressure fell 16 mb.

TABLE 22.—*Royal Center, Ind., wind and temperatures at 3 kilometers, March 30–31, 1920.*

1920	Mar. 30.			Mar. 31.	
Time	10 a. m.	5 p. m.	8 p. m.	12 midnight.	11 a. m.
Wind	W.	W.	WSW.	SW.	SW.
Temp., °C.	−9.0	−6.4	−5.0	−4.4	−2.4.

Surface wind, WSW. backing to S.; surface pressure stationary.

June 10–11, 1920, and January 6–7, 1922, Tables 23 and 24.—These two cases are very good examples of winter and summer types, respectively. In the one case we have steep temperature and pressure gradients and therefore vigorous cyclonic and anticyclonic development and movement; in the other, weak and irregular gradients and sluggish pressure conditions, "flat maps." These characteristic differences are strikingly reflected in the two sets of data above tabulated. In each case a wind with south component prevailed and a rise in temperature occurred, but in winter this rise amounted to more than 11° C. whereas in summer it was less than 3°. The difference may be said to be "one of degree, not one of kind."

TABLE 23.—*Broken Arrow, Okla., winds and temperatures at 3 kilometers, June 10–11, 1920.*

1920	June 10.			June 11.			
Time	10 a. m.	4 p. m.	8 p. m.	6 a. m.	9 a. m.	2 p. m.	5 p. m.
Wind	S.	SSW.	SSW.	SSW.	S.	SSW.	S.
Temp., °C.	6.6	8.6	6.5	8.3	8.4	9.6	9.4.

Surface wind, S.; surface pressure fell 2, then rose 6 and finally fell 3 mb. Gradients, both pressure and temperature, were of the summer type—weak and irregular. A moderate HIGH covered the Southeastern and Eastern States and an ill-defined LOW was central over the Dakotas. Temperature was only slightly higher in the South than in the North.

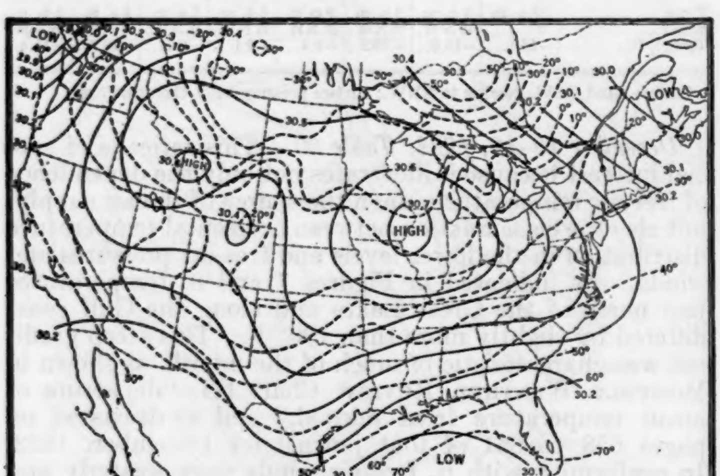

FIG. 7.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Dec. 18, 1922.

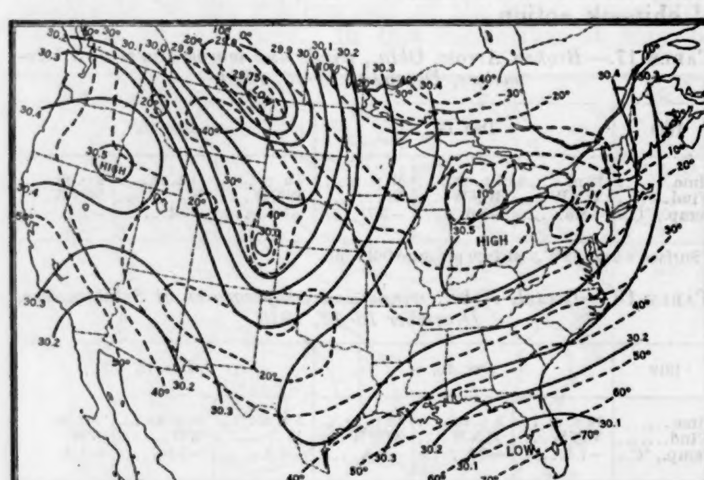

FIG. 8.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Dec. 19, 1922.

TABLE 24.—*Drexel, Nebr., winds and temperatures at 3 kilometers, January 6–7, 1922.*

1922	Jan. 6.		Jan. 7.			
Time	1 p. m.	9 p. m.	1 a. m.	5 a. m.	9 a. m.	1 p. m.
Wind	WSW.	SW.	SW.	WSW.	W.	WSW.
Temp., °C.	−16.2	−15.0	−14.8	−12.4	−7.5	−4.9.

Surface wind, S.; surface pressure fell 4 mb. A pronounced and well-developed HIGH covered the eastern part of the country on these two days, its center moving from Illinois and Iowa to the Lower Lake region. Weather conditions at Drexel were controlled by this HIGH throughout the series.

The temperature change at Drexel apparently increased with altitude, there being a rise of 9.8° C. from 1 p. m. to 9 a. m. at 4 kilometers. Increases in free-air temperature with southwesterly winds occurred on these two days also at Broken Arrow and Ellendale.

DECREASING TEMPERATURES WITH SOUTH COMPONENT WINDS.

There were 49 cases of this type, or 22 per cent of the total. For the most part the change in temperature was small, but in a few instances it was considerable. Data for a few of these are given in the following examples:

November 8–9, 1917, Table 25.—This period is remarkable in that practically no precipitation occurred in any part of the United States; in fact, from 8 a. m. of the 8th to the same hour of the 9th, 75th meridian time, the only rainfall reported was 0.01 inch at Tatoosh Island, Wash., and the same amount at Eastport, Me. Pressure was high everywhere; centers of activity were in the Plateau region and over the eastern half of the country, with only relatively low pressure between them. The western HIGH increased considerably in intensity from the 8th to 9th, and this development was accompanied by a material cooling on its eastern side, particularly in Utah and Colorado. Meanwhile a very weak LOW (its lowest pressure was above 30 inches) formed over western South Dakota and Nebraska. From this development of HIGH and LOW there resulted a more active circulation between the two, the SSW. winds at Drexel now bringing in colder air from the southeastern quadrant of the HIGH. The change occurred near midnight and was rather abrupt. Accompanying it was a very pronounced increase in relative humidity from 1 kilometer upward and the rapid formation of St Cu, following several days of practically cloudless weather. The temperature decrease was confined to a shallow stratum, there being none at 1 and 2 kilometers and less at 3½ than at 3 kilometers. This case is a very good example of polar air being brought southward on the eastern side of a HIGH and then diverted northward round a LOW in too short a time to enable it to assume the temperatures more or less approaching the normal of the latitudes which it passes.

TABLE 25.—*Drexel, Nebr., winds and temperatures at 3 kilometers, November 8–9, 1917.*

1917	November 8.				November 9.			
Time	12 m.	4 p. m.	7 p. m.	11 p. m.	2 a. m.	6 a. m.	11 a. m.	3 p. m.
Wind	S.	SSE.	SSW.	SSW.	SSW.	SSW.	SSW.	S.
Temp., °C	3.0	0.8	1.0	1.0	−3.4	−3.6	−1.6	−3.4.

Surface wind, SE.; surface pressure fell 7 mb.

June 9–10, 1920, Table 26.—High pressure with no well-defined center, overlay the Eastern States and there was a moderate LOW in the extreme Southwest. Temperature gradients were from E.–W. instead of N.–S., in other words, temperatures were lower west and southwest of the station than they were at the station itself; hence the SSW. winds at Drexel drew in air from a cooler region. It seems likely that this cooler air was first brought southward by a moderate HIGH that was central in Washington on the 9th. Thus it often happens that a HIGH or LOW which appears to have no direct relation to the weather at a given place may in reality, in an indirect way, be responsible for the changes that occur, which is only another way of saying that meteorological phenomena are never wholly local in character but are subject to influences whose only limits are those of the entire atmosphere itself.

TABLE 26.—*Drexel, Nebr., winds and temperatures at 3 kilometers, June 9–10, 1920.*

1920	June 9.			June 10.				
Time	9 a. m.	4 p. m.	8 p. m.	12 midnight.	4 a. m.	7 a. m.	11 a. m.	3 p. m.
Wind	WSW.	SSW.	SW.	SW.	SW.	SSW.	SSW.	SSW.
Temp., °C.	10.5	9.4	9.2	8.2	8.0	8.2	7.2	6.8.

Surface wind, WSW. backing to SSW.; surface pressure stationary.

The northwestern HIGH diminished in intensity from the 9th to 10th and as a result the southward flow of cool air ceased. Hence, it is found that free-air temperatures at Drexel increased during the 24 hours following this series, i. e., from the 10th to 11th, with SSW. winds; also at Broken Arrow as shown in Table 23 and accompanying discussion.

May 25–26, 1922, Table 27.—This series is of special interest not only as showing polar air from a southerly quarter, but also because of the prevalence of easterly winds to great heights. Pressure and temperature conditions over the country at 8 a. m., 75th meridian time, of each day are shown in Figures 9 and 10. The air in the

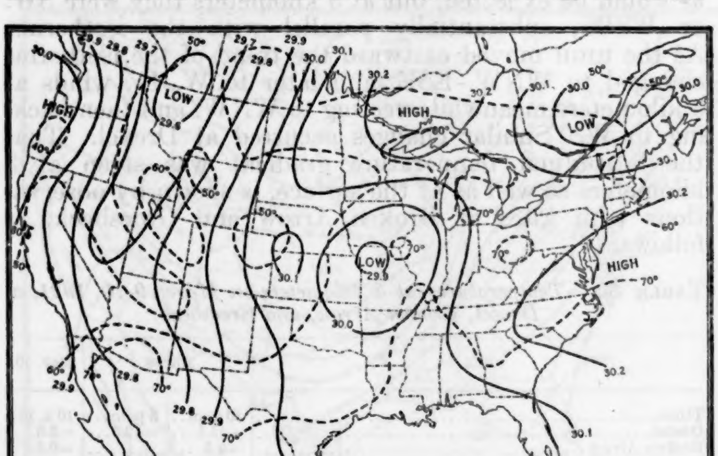

FIG. 9.—Pressure and temperature distribution, 8 a. m., 75th meridian time, May 25, 1922.

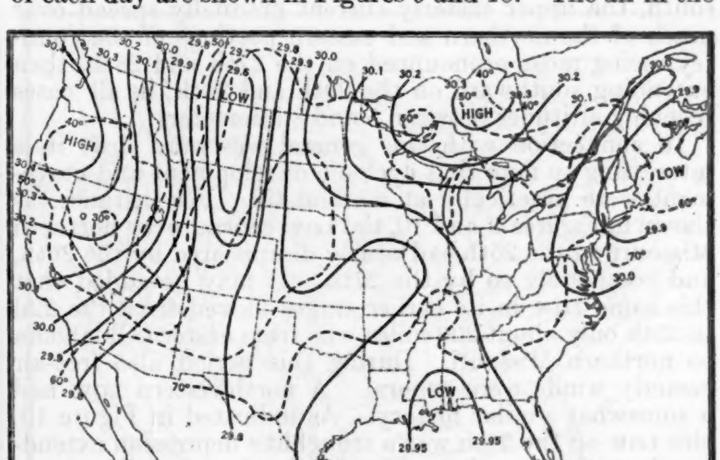

FIG. 10.—Pressure and temperature distribution, 8 a. m., 75th meridian time, May 26, 1922.

SE. and ESE. winds at Ellendale on the 26th evidently originated from the eastern side of the HIGH central north of the upper Lakes. This view is supported by observations at Lansing and Madison, where the free-air winds were NE. and E., respectively. On the following day, 27th, the same wind structure prevailed, viz, NE. at Lansing, E. at Madison, and SE. at Ellendale. By this time, however, the HIGH had developed further and spread eastward and temperatures had appreciably risen. As a natural consequence we find that, between the 26th and 27th, a small increase in free-air temperature at Ellendale occurred. It is worthy of note also that even from the 25th to 26th the decrease at Ellendale, as in some cases previously discussed, did not extend much above 3 kilometers. At 4 the change was only about 1° C.

TABLE 27.—*Ellendale, N. Dak., winds and temperatures at 3 kilometers, May 25–26, 1922.*

1922	May 25.			May 26.		
Time	1 p. m.	6 p. m.	11 p. m.	5 a. m.	10 a. m.	1 p. m.
Wind	E	E	E	SE	SE	ESE.
Temp., °C.	5.8	5.6	5.1	4.2	3.8	1.0.

Surface wind, ESE.; surface pressure practically stationary.

Further inspection of Figures 9 and 10 shows that unusually high temperatures for this season of the year prevailed in the northern part of the country and that the gradient southward was very small. It is not surprising, therefore, to find free-air easterly winds, particularly since the temperature distribution was associated with a higher pressure in the North than in the South. That these winds were of great vertical extent is indicated by a balloon run at Ellendale on the morning of the 25th, when ENE. backing to NNE. were observed between 3,500 and 7,000 m. There was a further backing to NNW. at 10 kilometers, but at all levels the speed was low, averaging 5 to 6 m. p. s. Very much the same condition prevailed on the afternoon of this day, but by the 26th the speed had increased to about 15 m. p. s. and the direction had veered to SE at heights between 1 and 5 kilometers. A kite flight on the 27th showed that the wind was still SE. at 4 kilometers, although the speed had diminished to about 10 m. p. s.

With the development and eastward extension of the upper Lakes HIGH, already referred to, and the continuation of a weak temperature gradient from the north to south, the upper easterly current gradually spread over much of the northern and eastern portions of the country, being most pronounced on the 27th and 28th, then extending southward on the 29th and 30th; in all cases reaching altitudes between 5 and 8 kilometers.

In connection with this general westward drift it is interesting to note that cyclonic development and movement were practically at a standstill. For instance, as shown in Figures 9 and 10, the LOW central over northern Missouri on the 25th had nearly disappeared by the 26th, and completely so by the 27th. It may be added that this same LOW in its earlier stages moved from the 22d to 25th only about 200 miles, viz, from eastern Oklahoma to northern Missouri. During this period also free-air easterly winds were general. A northwestern LOW had a somewhat similar history. As indicated in Figure 10, this LOW on the 26th was a troughlike depression extending from just north to just south of eastern Montana. On the 27th practically no trace of it remained, an excellent example of a "dying cyclone," because of little temperature variation on all sides. As already stated, the upper easterly current extended southward after the 28th and in this connection it is significant to note that a LOW of small intensity but accompanied by considerable precipitation remained in practically a stationary position just south of Mississippi and Alabama from the 28th to 31st.

INCREASING TEMPERATURES WITH WIND CHANGING FROM NORTH TO SOUTH COMPONENT.

Of the 42 series of observations made with this type of wind change (see Table 11) 86 per cent showed a progressive increase in free-air temperatures, the increase usually being very pronounced. Data for two series on March 9–10, 1921, at Drexel and Royal Center are given in Tables 28 and 29.

TABLE 28.—*Drexel, Nebr., winds and temperatures at 3 kilometers, March 9–10, 1921.*

1921	Mar. 9.				Mar. 10.	
Time	9 a. m.	1 p. m.	5 p. m.	9 p. m.	1 a. m.	2 p. m.
Wind	WNW	WNW	WNW	WSW	WSW	W.
Temp., °C.	−16.2	−13.8	−11.2	−11.8	−9.0	−2.6.

Surface wind WSW.; surface pressure fell 15 mb; weather generally clear, except for 5/10 to 7/10 Ci and Ci St between 4 and 8 p. m. on the 9th.

TABLE 29.—*Royal Center, Ind., winds and temperatures at 3 kilometers, March 9–10, 1921.*

1921	Mar. 9.			Mar. 10.			
Time	11 a. m.	3 p. m.	7 p. m.	2 a. m.	7 a. m.	10 a. m.	2 p. m.
Wind	SW	WSW	WNW	WNW	WSW	W	W.
Temp., °C.	−9.7	−10.7	−12.8	−11.0	−8.7	−6.7	−6.7.

Surface wind NNW. backing to SSW.; surface pressure rose 6 then fell 3 mb; during the first day there was considerable cloudiness of intermediate types; after 6 p. m. weather was clear.

These two series, when considered together and in connection with the weather maps, bring out some interesting points. For one thing they show the essential conformity of free-air winds, i. e., isobars, to horizontal temperature gradients, to a large extent regardless of changes in surface pressure distribution introduced by passing HIGHS and LOWS. This is clearly seen by comparing the wind directions at 3 kilometers, as above tabulated, with the pressure and therefore wind changes occurring at the surface as shown in Figures 11 and 12. On the 9th at Royal Center surface winds were NNW., as would be expected, but at 3 kilometers they were SW. or WSW., substantially parallel with the isotherms. As the HIGH moved eastward the trend of the isotherms changed to WNW.-ESE. and later to W.-E., winds at 3 kilometers meanwhile veering to WNW. and then backing to W. Similar changes occurred at Drexel. That the latitudinal temperature gradient was steep at 3 kilometers as well as at the surface, is shown by observations with kites at Broken Arrow and Groesbeck, as follows:

TABLE 30.—*Temperatures at 3 kilometers on March 9-10, 1921, at Drexel, Broken Arrow, and Groesbeck.*

1921	Mar. 9.		Mar. 10.
Time	10 a. m.	3 p. m.	10 a. m.
Drexel	−15.5	−12.5	−5.0.
Broken Arrow	−9.5		−0.6.
Groesbeck		0.2	

The normal difference at 3 kilometers in March between Drexel and Broken Arrow is 3.9° C., and between Drexel and Groesbeck, 7.3° C.

Observations with pilot balloons also show that in all parts of the country east of the Rockies and north of central Florida winds at 3 kilometers were between SW. and NW. and in 75 per cent of the cases they were between WSW. and WNW.

It is significant that the HIGH shown in Figures 11 and 12 moved almost directly east from the 9th to 10th, in close agreement with the air movement generally prevailing at 3 kilometers. It is interesting further to note that on the morning of the 8th winds above 2 kilometers at Ellendale and Drexel were NNW. to WNW. At this time the HIGH was central just north of Montana. Its movement south-southeastward was in good agreement with the trend of the isotherms and the resulting free-air winds.[9]

The foregoing discussion constitutes to some extent a digression from the main purpose of this paper, but in studying any body of meteorological data one usually comes across many points of interest which seem to merit some attention but which would very likely not receive such attention unless first introduced as "side issues," so to speak. Later these may themselves become the bases of separate studies. We shall now return to the subject in hand.

The dependence of free-air temperatures upon the source of the air supply is convincingly shown in the tabulations above given for Drexel and Royal Center. The HIGH, central north of Montana on the morning of the 8th, brought with it a large mass of polar air. At Drexel on this morning wind and temperature at 3 kilometers were WNW. and −11°C., respectively. As the HIGH moved southward the wind remained WNW. or perhaps veered to NW. and the temperature continued to fall—to what value is not known, but at 9 a.m. on the 9th it was −16.2°C. Thereafter with the eastward movement of the HIGH and the accompanying change in the trend of surface isotherms the wind at 3 kilometers gradually backed to WSW. and the temperature rose very decidedly.

The records at Royal Center are of special interest in that they show the temperature changes accompanying a change in wind from south to north and later from north to south component. In the first flight on the 9th at 11 a. m. the wind at 3 kilometers was still SW. in substantial parallelism with the surface isotherms, although the influence of the HIGH was already apparent in the lower levels, the winds there being NNW. By 7 p. m., the winds at 3 kilometers had veered to WNW. and the temperature had fallen from −9.7° to −12.8° C. Thereafter, with further advance of the HIGH past the station and accompanying change in the isothermic distribution the winds backed to WSW. and W. and the temperature rose to −6.7° C. On the 11th this HIGH was central some distance off the middle Atlantic coast, the wind at 3 kilometers was WSW. and the temperature had risen still further to −3.2° C.

During the latter part of this month a series of 8 flights at Ellendale, made in connection with rapid and pronounced changes in pressure, gave an excellent illustration of the normal relation between free-air winds and temperatures, as discussed in the following paragraphs.

March 28–29, 1921, Table 31.—This series was made near the end of a period of exceptional barometric activity, the main features of which, so far as meteorological conditions at Ellendale are concerned, was a well-developed HIGH preceded and followed by equally well-developed LOWS. The first LOW assumed definite character on the morning of the 26th when it was central over southeastern Colorado, the lowest pressure being 29.2 inches. During the next 24 hours it moved, with undiminished vigor, to Lake Superior and was accompanied by general precipitation and high winds. Thereafter it decreased in energy and passed eastward to the St. Lawrence Valley.

TABLE 31.—*Ellendale, N. Dak., winds and temperatures at 3 kilometers, March 28–29, 1921.*

1921	Mar. 28.					Mar. 29.		
Time	8 a. m.	1 p. m.	4 p. m.	8 p. m.	11 p. m.	3 a. m.	8 a. m.	12 m.
Wind	NW	NW	NW	WNW	WNW.	W	WSW.	WSW.
Temp. °C	−16.6	−13.4	−10.8	−10.0	−7.1	−3.3	−4.1	−5.2

Surface wind S. veering to SSW.; surface pressure fell 34 mb. (1 inch); weather generally cloudy—mostly A Cu, A St, and Ci St.

Meanwhile a HIGH which appeared in the Canadian Northwest on the 26th advanced southward and was central over Iowa and Nebraska on the morning of the 28th. Thereafter it diminished somewhat in intensity and moved eastward to the Atlantic. A severe cold wave accompanied this HIGH, progressively overspreading sections farther and farther east, and wrought serious damage to all early fruit and much of the later varieties

[9] For a discussion of the relation between free-air winds and the movements of HIGHS and its aid in forecasting, see "Relation between rate of movement of anticyclones and the direction and velocity of winds aloft," by C. L. Mitchell. MO. WEATHER REV., May, 1922, 50: 241–242.

FIG. 11.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Mar. 9, 1921.

FIG. 12.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Mar. 10, 1921.

over most of the central part of the country. This destruction was especially severe because of abnormally high temperatures which had prevailed during most of the month. The HIGH was followed by a well developed LOW which on the morning of the 29th was central north of the Dakotas with a pressure of 29.2 inches or lower.

Throughout this period a close relationship was found between free-air winds and temperatures. The crest of the cold wave reached Ellendale on the 27th, with the HIGH to the northwest and the LOW central over Lake Superior. Upper winds at Ellendale were generally northwesterly, in close agreement with the trend of the isotherms and with the HIGH's path during the next 24 hours. Temperature at 3 kilometers was −22.4° C. By the next morning, 28th, the HIGH had advanced some distance south of the station and a well-developed LOW was coming in from the northwest, accompanied by a marked rise in temperature. Surface isobars and isotherms between these two systems intersected almost at right angles, with the result that winds in the lower levels at Ellendale were southerly, whereas they were still northwesterly in the upper levels. However, the latter were now bringing in air from a distinctly warmer region than on the day previous under the influence of the LOW. Hence, as shown in Table 31, the temperature at 3 kilometers had increased from −22.4° to −16.6° C. With the eastward movement of both HIGH and LOW from the 28th to 29th the upper winds gradually backed to WSW. and the temperature at 3 kilometers rose with this change to about −4° C. It is interesting to add that on the following day, 30th, with a wind change back to NW., the temperature had fallen to −18° C.

DECREASING TEMPERATURES WITH WIND CHANGING FROM NORTH TO SOUTH COMPONENT.

There were only two cases, 5 per cent of the total, showing a decrease in temperature with this type of wind change, and in each case the amount of the decrease was only 2° to 3° C.

January 24–25, 1921, Table 32.—During this series a fairly well-developed LOW was central in Kansas and practically stationary, and a pronounced HIGH moved east-southeastward from north of Minnesota to north of the upper Lakes, producing colder weather in the Lake region and adjacent districts. It is evident that the ESE. and E. winds at 3 kilometers during the latter part of the series at Ellendale were in reality of polar origin, this air having been brought in bodily by the southward movement of the HIGH. The existence of these upper easterly winds is in itself a matter of interest in view of the rather large north to south temperature gradient. However, the pressure gradient in the lower levels between the HIGH and the LOW was sufficiently steep to offset this influence up to 3 kilometers where the pressure at Drexel and Ellendale was almost identical and the winds therefore of low speed. Cloud observations show that the winds shifted into a westerly quarter at no great height above 3 kilometers.

TABLE 32.—*Ellendale, N. Dak., winds and temperatures at 3 kilometers, January 24–25, 1921.*

1921.	Jan. 24.				Jan. 25.
Time	11 a. m.	3 p. m.	7 p. m.	11 p. m.	4 a. m.
Wind	E.	ENE.	ESE.	ESE.	E.
Temp., °C.	−6.0	−5.6	−6.7	−8.0	−8.4

Surface wind ENE. backing to NNE.; surface pressure stationary.

In connection with these easterly winds it is significant that the LOW, as already stated, moved very little, only across the state of Kansas—from the 24th to 25th. South of it the upper winds, as observed at Groesbeck, were westerly but very light on the 24th; by the 25th they had increased in strength sufficiently to cause a more rapid movement of the LOW, which on the 26th was central over western Florida. By this time the area of upper easterly winds had advanced east-southeastward with the HIGH but was of limited extent, covering only the region from Indiana to Virginia. Its presence, however, rendered impossible a northward component in the course of the LOW which, as already stated, moved southeastward under the influence of the stronger westerly current still farther south. By the 27th the HIGH had moderated greatly in intensity, easterly winds no longer prevailed at great heights and the LOW was moving slowly east-northeastward some distance off the Atlantic coast.

DECREASING TEMPERATURES WITH WIND CHANGING FROM SOUTH TO NORTH COMPONENT.

Table 11 shows 32 series of observations with this type of wind change. In 62 per cent of these free-air temperatures decreased quite markedly. A good illustration of such decrease is afforded by a series of 7 successive kite flights at Ellendale, N. Dak., on September 24–25, 1918. This series has special interest in that the free-air winds

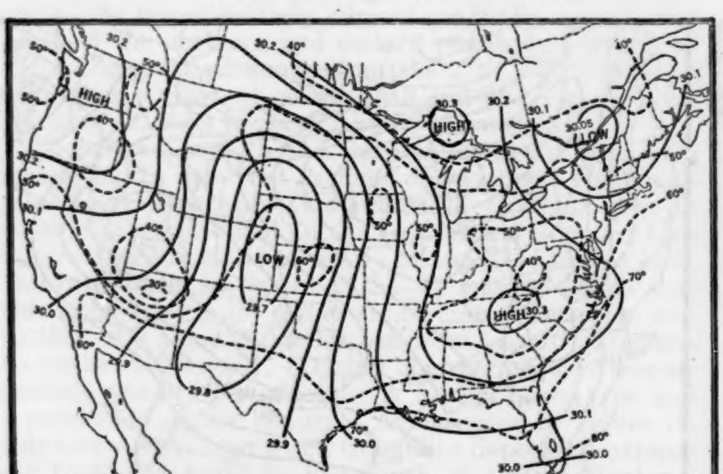

FIG. 13.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Sept. 24, 1918.

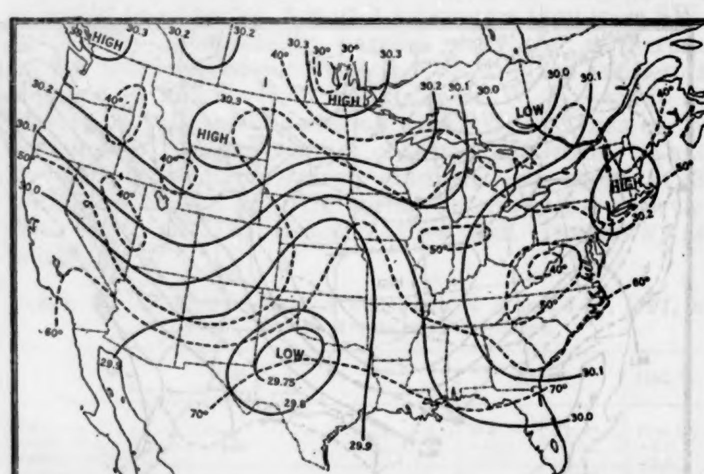

FIG. 14.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Sept. 25, 1918.

up to at least 4 kilometers had an east instead of a west component and were associated with a LOW whose course for this season of the year was decidedly abnormal. The wind and temperature conditions at 3 kilometers are given in Table 33.

TABLE 33.—*Ellendale, N. Dak., winds and temperatures at 3 kilometers, September 24–25, 1918.*

1918	Sept. 24.				Sept. 25.		
Time	9:30 a. m.	1:30 p.m.	6 p. m.	10 p. m.	2 a. m.	6:30 a. m.	11:30 a.m.
Wind, m. p. s.	SSE. 10.	SSE. 8.	E. 12.	ESE. 10.	E. 14.	ENE. 12	NE. 14.
Temp. °C.	6.0	7.0	4.0	1.0	2.4	3.3	2.6.

Winds at the surface were easterly and fairly strong, 10 to 15 m. p. s., in the early part of the series, backing to NNE. and diminishing to 6 to 8 m. p. s. at about midnight. Surface pressure was nearly stationary at 962 mb. until 6 p. m. of the 24th, after which it rose gradually to 971; meanwhile the pressure at 3 kilometers rose from 710 to 714 mb. The change in pressure distribution at Ellendale was very definitely from cyclonic to anticyclonic, as indicated in Figures 13 and 14. The southeasterly winds at 3 kilometers on the 24th and the northeasterly winds on the 25th were distinctly of equatorial and polar origin, respectively. The wind shift occurred first at and near the surface and later progressively at higher and higher levels until on the 25th there was a solid northeasterly current reaching at least to 4 kilometers with little variation in speed, the average being about 12 m. p. s. There were no high clouds on this day, and no free-air observation was made on the 26th, but on the 27th there were about 8/10 Ci St. moving from northeast, notwithstanding that winds up to 5 kilometers were westerly with a speed of 15 to 18 m. p. s. By this time the HIGH north of Ellendale on the 25th had moved southward and covered a wide area, with its center over Nebraska, as shown in Figure 15. It was attended by relatively cool weather whereas farther north the temperatures were from 10° to 15° F. higher, a difference sufficiently large to reverse the pressure gradient at the cirrus level and probably for some distance below it.

The easterly current not only reached great altitudes but also gradually extended over a considerable portion of the interior of the country. Free-air winds at Drexel were southerly on the 24th, backing to southeasterly on the 25th and still farther to northeasterly up to 4,300 meters on the 26th. In all cases these winds were moderately strong, about 12 to 15 m. p. s. except at 3,500 to 4,300 meters on the 26th where their speed fell to 8 m. p. s. This day was cloudless, but on the 27th there were a few Ci from east-southeast. Cloud movement in general, including the cirrus and other high level forms was from east or northeast over the southern and southeastern States on the 27th and 28th.

This deep and widespread easterly drift appears to have been closely associated with a LOW which, first appearing in Idaho on the 21st, gradually moved in a general south-southeastward direction to the Gulf, thence eastward to Florida. The path of this LOW is shown in Figure 16, and its form and position in more detail on the 24th, 25th, and 27th in Figures 13, 14, and 15. Examination of records during the 10-year period, 1913 to 1922, inclusive, brings out the fact that no other LOW has followed a course at all resembling this one during the month of September and only 2 were at all similar to it during the months June to October. The portion of this LOW's journey which is particularly abnormal is that from the 24th to the 26th. During this period temperatures at Drexel and Ellendale between 1 and 3 kilometers were practically the same; hence, free-air isobars conformed closely with those at sea level. On the 24th pressure at 1 and 3 kilometers was identical at the 2 places; on the 25th it was higher by 8 or 9 mb. at Ellendale than at Drexel, a decided reversal of the normal condition. The sea level map of the 24th, Figure 13, shows a fairly steep and approximately uniform pressure gradient on the north, east, and west sides of the LOW, with a somewhat weaker one on the south side.

A 2-kilometer map, Figure 17, prepared in accordance with Meisinger's system of reduction,[10] indicates nearly the same condition with the exception that the major axis extended NNW.-SSE. instead of NNE.-SSW. This free-air distribution of pressures and winds would imply a stationary or at most a slow-moving LOW, and would make impossible a movement to the north, east, or west. To the south, however, the pressure gradient, surface and aloft, was somewhat weaker and in addition there was, as already stated, a lack of symmetry here, the upper isobars crossing those at sea level. The southeastward extension of the LOW is yet more marked at higher levels, as shown in Figure 18, which gives the pressure distribution at 3 kilometers.[11] At 4 kilometers,

[10] The preparation and significance of free-air pressure maps for the central and eastern United States. MO. WEATHER REV. SUPPLEMENT NO. 21. W. B. No. 784. 1922.

[11] For the method of computing pressures at 3 and 4 kilometers see "The law of pressure ratios and its application to the charting of isobars in the lower levels of the troposphere." by C. Le Roy Meisinger, MO. WEATHER REV. September, 1923. 51:437–448. It is interesting to note that the *computed* pressure at Omaha was 20.94 inches, and the *observed* pressure at Drexel, 20 miles west, was also 20.94 inches.

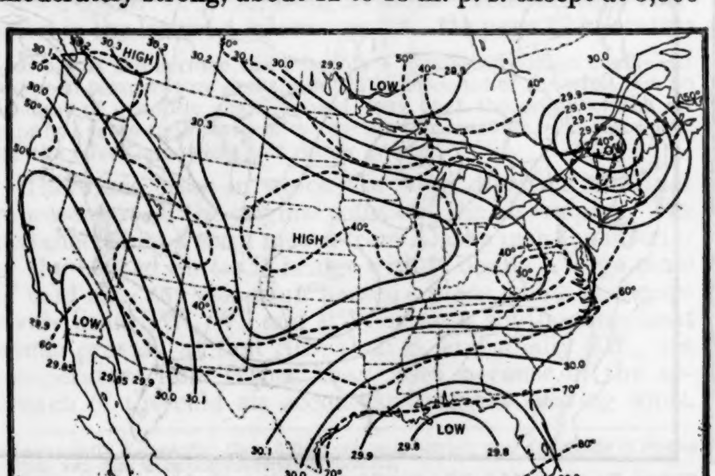

FIG. 15.—Pressure and temperature distribution, 8 a. m., 75th meridian time, Sept. 27, 1918.

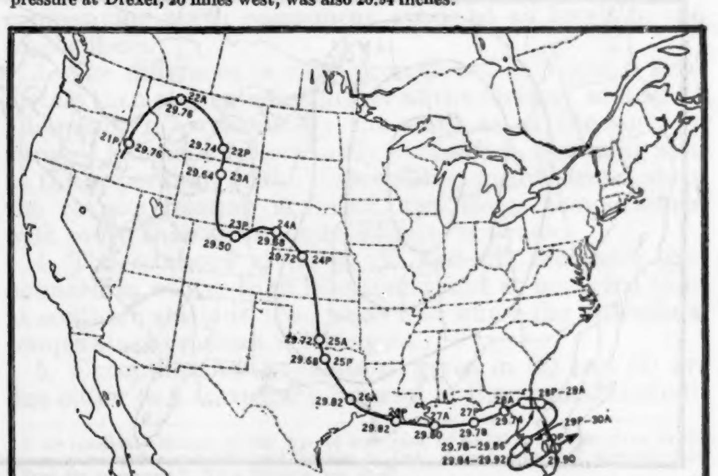

FIG. 16.—Track of center of LOW from Sept. 21 to 30, 1918, inclusive.

the map for which is not reproduced here, the pressure was about the same over Arkansas and over Wyoming, with somewhat higher pressure between the two centers. This free-air pressure distribution is decidedly abnormal, there being ordinarily a northwestward shift of the LOW center with altitude. The presence of the free-air LOW to the southeast of its sea level position seems in this case to have been due to comparatively low temperatures at and near the surface in the southern part of the country. As indicated in Figure 13, surface temperatures varied little from Texas to Wisconsin. Apparently there was a reversal in the upper levels, a kite flight at Broken Arrow showing a temperature 2° C. lower at 1,000 meters than that observed at Drexel. Unfortunately the observation at Broken Arrow extended only to this height.

The free-air pressure distribution above outlined appears to have been influential in determining the course of the sea-level LOW. Its movement eastward was blocked by the upper easterly winds already referred to. Southward, however, as indicated in Figures 13, 17, and 18, there was a marked difference in the isobars at the surface and in the free air, the two systems being approximately at right angles to each other. This condition, coupled with the probably greater strength of the northwesterly winds on the western side of the LOW than of the southeasterly winds on its eastern side, seems to provide the correct explanation of the observed southward movement. Such movement would have been evident to the forecaster on the morning of the 24th, possibly on the evening of the 23d, had he possessed all of this information as to free-air pressures and winds at those times. In this connection it is interesting to recall that in Japan, where pressure maps for the 3-kilometer level have been used for several years, one of the "rules" resulting from this use is:[12] "Most cyclones showed decided tendencies to move toward the region where unmistakable cross-intersections of upper and lower isobars could be perceived."

A feature of added interest in connection with this LOW is the entire absence of precipitation on its eastern and southern sides until it reached the Gulf on the 26th. North and west of its center, however, rain was general. As the free-air winds changed from southerly to northerly, introducing lower temperatures, relative humidities at both Drexel and Ellendale increased markedly, particularly at 2 to 3 kilometers. A decrease to very low values took place subsequently with the continuance of these northerly winds. While the LOW was traveling eastward along the Gulf coast precipitation was general and in many cases excessive.

Numerous other cases could be cited in which a decrease in temperature at 3 kilometers occurred with a change from south to north component in the wind. As a rule the observations were made with a LOW to the north of the station passing eastward or else with the station successively under the influence of an eastern and a western HIGH. Station pressure either rose continuously or first fell slightly and then rose; in nearly all cases it was higher at the end than at the beginning of the observations. The amount of the temperature decrease was dependent primarily upon the steepness of the latitudinal gradient; to some extent also upon the angle through which the wind changed. The time of the wind change usually coincided very closely with that of largest temperature change.

November 11–12, 1918, Table 34.—During this series the station was first under the influence of a HIGH over the St. Lawrence Valley; later, of a HIGH central over Northwest Wyoming. An interesting feature is the recovery of temperature with a change from NNW. to WNW. wind between the last two flights.

TABLE 34.—*Drexel, Nebr., winds and temperatures at 3 kilometers, November 11–12, 1918.*

1918.	Nov. 11.				Nov. 12.		
Time	9 a. m.	1 p. m.	5 p. m.	9 p. m.	1 a. m.	4 a. m.	8 a. m.
Wind	WSW.	WSW.	W.	WNW.	NNW.	NNW.	WNW.
Temp. °C	2.1	2.0	2.1	−0.5	−1.7	−4.0	−1.5.

Surface wind SSW. veering to NNW.; surface pressure fell 3, then rose 11 mb.

INCREASING TEMPERATURES WITH WIND CHANGING FROM SOUTH TO NORTH COMPONENT.

This type of wind change was accompanied by increasing temperatures in 7 cases, or 22 per cent of the whole number. The increase was small, however, amounting in no case to more than 3° or 4° C. A good example is found in a series of 4 flights at Due West, S. C., on October 11–12, 1922.

[12] Sekiguchi, Rikichi. High level isobars as used in everyday weather service. MO. WEATHER REV., May, 1922. 50: 242–243.

FIG. 17.—Pressure distribution at 2 kilometers, 8 a. m., 75th meridian time, Sept. 24, 1918.

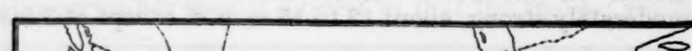

FIG. 18.—Pressure distribution at 3 kilometers at 8 a. m., 75th meridian time, Sept. 24, 1918.

TABLE 35.—*Due West, S. C., winds and temperatures at 3 kilometers, October 11–12, 1922.*

1922	Oct. 11.			Oct. 12.
Time	10 a. m.	2 p. m.	7 p. m.	1 a. m.
Wind	WSW.	WSW.	WNW.	WNW.
Temp., °C.	0.8	3.5	4.6	4.1

Surface wind WSW.; surface pressure fell 1, then rose 3 mb.

During this series a well-developed LOW, central over the Lake region, moved rapidly northeastward to the St. Lawrence Valley, and was followed by a vigorous HIGH whose influence, however, was not felt at Due West until after these flights were completed. It is to be noted that the larger part of the increase occurred between the first and second flights in both of which the wind at 3 kilometers was from WSW. There was a further increase of 1.1° C. as the wind veered to WNW., but the last observation showed a slight decrease with NW. wind. These changes are easily accounted for: Temperatures were essentially uniform in all parts of the LOW, from the upper Lakes southward nearly to the Gulf; still farther south there was a moderate gradient. The WSW. winds at Due West drew from this warmer region; hence, the temperature rose. The WNW. winds, however, came from a region in which the temperatures were practically the same as at Due West; therefore, changes at the latter were unimportant.

SUMMARY AND CONCLUSIONS.

The purpose of this paper, as stated at the beginning, is to determine, so far as possible, the relations between free-air temperatures and wind directions in this country. Before presenting the conclusions, it may be stated that wind direction is of importance mainly in so far as it represents the original source of the air supply. Granting this, it follows that contrasts in temperature with different wind directions are large or small in proportion to the steepness of the latitudinal temperature gradient. As is well known, this gradient is very pronounced in this country but comparatively weak in Europe owing to the marked difference in the climates, one being continental and the other marine, and also because of the effects of the Gulf Stream.[13] As would be expected, therefore, we find greater contrasts in the temperatures accompanying northerly and southerly winds in this country than in Europe. Nevertheless, even in that continent the relationship is direct, on the average, as shown by Mr. C. K. M. Douglas in his "Temperature variation in the lowest 4 kilometers."[14] On page 27 he states:

> Even at the surface there is only a small correlation coefficient between temperature and the south component of the wind but no student of synoptic charts would deny that the origin of the air supply has an important effect on the temperature. In the upper air the effect is not less but rather greater.

There are cases in which the wind direction does not represent at all the original source of the air supply. For instance when a HIGH moves from Alaska into the interior of the United States it brings with it bodily a large mass of cold air. As this HIGH passes a place which is successively in its SW., W., and NW. octants, south component winds prevail, at first SE., then S, and finally SW., yet temperature falls rather than rises because of the approach of the cold air accompanyimg the moving HIGH. In other words, the trajectory of a particle of air passing the place in question is southward instead of northward. The effect of this motion of translation of the HIGH depends upon the rapidity of that motion, as compared with the speed of the winds themselves.

Another and much more frequent case in which the wind direction does not represent the source of the air supply is that of a nearly, or quite, stationary HIGH or LOW around which a fairly definite and characteristic circulation has been established. The most common exception is a HIGH, nearly circular, with its center over Utah or Wyoming.[15] The free-air winds in the northeast quadrant of such a HIGH are WNW. to NNW. and the accompanying temperature not infrequently rises. In every case studied it was plain that the air in this northwesterly wind had originated from the western part of the HIGH at a lower latitude than that of the station itself. Douglas, in the paper above quoted, cites several similar cases in Europe. When a HIGH extends well up into Canada, no such warming occurs, but instead the temperature falls decidedly, the air coming from a long distance to the north.

A type of exception that occurs only in summer is that associated with a complete reversal of latitudinal temperature gradient, with weather sometimes hotter even in southern Canada than in the Southern States. Such exceptions are rare, however.

It is not to be thought that in any region wind direction is the *only* factor to be considered. Other influences, such as radiation intensity, changes in barometric pressure, differences in the quantity and distribution of water vapor, and vertical movement of the air are in operation at all times, each contributing to the final result.[16] But in all considerations of the subject wind direction or the source of the air supply must be included. In regions of little temperature contrast its influence is largely masked by the others; in regions and at times of large horizontal temperature gradient it exercises a larger control than do all of those combined.

With the foregoing remarks in mind, we can state briefly the general conclusions as follows, so far as conditions in the United States are concerned.

1. A north or south component in the winds at and near the surface persists in a majority of cases at all levels in the troposphere and presumably well up into the stratosphere, although the wind direction itself usually changes, e. g., NNW. backing to NW. or WNW.; SE. veering to SW. or WSW.

2. Temperatures accompanying south component winds are on the average considerably higher than those accompanying north component winds at all levels in the troposphere.

3. The difference is more pronounced at 1 and 2 kilometers than at greater heights or at the surface; at 3 and 4 kilometers it is essentially the same as at the surface; above 4 kilometers it gradually diminishes, becoming zero at the upper limit of the troposphere; in the stratosphere the reverse relation is found, viz. lower temperatures with south than with north component winds.

4. The relations given in (2) and (3) are more pronounced in winter than in summer and at northern than at southern stations, i. e., when and where the latitudinal temperature gradient is strongest.

5. Exceptions to the relations given in (2) and (3) are due either to a temporary reversal in the normal latitudi-

[13] Apparently disregarding these differences, some writers treat the results of studies of their own data as having universal application.

[14] *Quarterly Journal of the Royal Meteorological Society.* Vol. XLVII. No. 197, January 1921, pp. 23–43.

[15] An excellent example of this type of exception, in addition to those given in this paper, is that of Jan. 4–5, 1924, at Ellendale, N. Dak., described by L. T. Samuels under "Free-Air Summary." This REVIEW, pp. 46–48.

[16] Humphreys, W. J.: *Physics of the Air*, pp. 53–57. Philadelphia, Pa. 1920.

nal distribution of temperature (occasional summer condition) or to the importation of large masses of cold or warm air in rapidly moving HIGHS or LOWS or to the fact that in some instances the wind direction does not represent the original source of the air, the latter having followed a curved path round a nearly stationary HIGH or LOW.

6. Changes from north to south component winds are in nearly all cases accompanied by rising temperatures, and vice versa.

7. Owing to effects of temperature on air density, the free-air position of a LOW is usually to the northwest of its sea-level position, and that of a HIGH to the southwest. Winds therefore are southwesterly above the sea-level positions of LOWS and northwesterly above the sea-level positions of HIGHS. Under these conditions the air above LOWS is on the average warmer than that above HIGHS, the effects of importation being much greater than those of vertical movement.

8. When easterly winds prevail from the surface up to 3 or 4 kilometers, HIGHS and LOWS are either stationary or their movements are slow and erratic. Such HIGHS and LOWS are nearly circular and probably symmetrical to great heights, air circulation in them is fairly definite and steady, and the effects of vertical movement of the air are greater than those of importation, the centers of HIGHS being warmer than the centers of LOWS.

9. Since in this country symmetrical HIGHS and LOWS, referred to in (8), are less frequent than those with a westward shift of the centers, referred to in (7), it follows that the air above the sea-level positions of HIGHS is on the average colder than that above the sea-level positions of LOWS. If, however, we take the lowest and highest pressures at different heights as the basis of comparison, we find that the lowest pressures are accompanied by the lowest temperatures, the pressure itself at any level being largely a function of the mean temperature of the air column beneath.

A PRELIMINARY STUDY OF PRECIPITATION IN RELATION TO WINDS AND TEMPERATURE.

By V. E. JAKL, Meteorologist.

(Weather Bureau, Washington, D. C., Dec. 11, 1923.)

As a preliminary step to a more detailed study of upper-air conditions attending precipitation, a statistical study has been made of surface wind directions attending precipitation at the Drexel Aerological Station, Nebraska. The object is to reconcile the frequency, duration, and intensity of precipitation by seasons with position relative to adjoining centers of high and low pressure, or more strictly, with direction of surface isobars. Such a study should form a basis, from which, considered in connection with statistical data already compiled for the upper air, inferences may be drawn relative to the conditions of the atmosphere when precipitation is occurring.

The tabulation in Table 1, column 3, giving the frequency of precipitation in percentage for all parts of a LOW is shown in Figure 1. This figure is intended to be the simplest possible method of showing the sense of direction of the winds relative to the surface isobars; in other words, the directions in Table 1 have been oriented about the center of a composite or imaginary center of low pressure. To allow for the convergence of the arrows toward the center, the table of average deviation of free-air winds from surface winds [1] has been considered, but not strictly adhered to, an average deviation of 20° of surface winds from surface isobars being assumed for all directions and all seasons. Without going into too great detail, and giving separate recognition to the different conditions, this assumption is undoubtedly justified as a general average. Moreover, the averages for all aerological observations can not be rigidly applied to the rather special conditions prevailing during precipitation.

[1] Gregg, W. R.: An Aerological Survey of the United States. MO. WEATHER REV. SUPPLEMENT No. 20, fig. 55, 1922.

TABLE 1.—*Frequency, amount and duration of precipitation with reference to wind direction and season.*

Direction.	Number of times precipitation occurred.	Percentage of observations for all directions.	Average amount of precipitation.	Average duration of precipitation.
SPRING.			*Inches.*	*Hours.*
N.	26	11	0.29	7
NE.	55	23	0.36	8
E.	29	12	0.32	8
SE.	46	19	0.35	6
S.	22	9	0.22	4
SW.	13	5	0.07	2
W.	10	4	0.23	2
NW.	42	17	0.25	4
SUMMER.				
N.	22	7	0.19	3
NE.	54	19	0.36	3
E.	34	12	0.41	3
SE.	57	20	0.39	4
S.	26	9	0.23	3
SW.	38	13	0.20	2
W.	14	5	0.19	1
NW.	45	15	0.22	2
AUTUMN.				
N.	21	12	0.28	11
NE.	44	25	0.40	9
E.	15	8	0.20	6
SE.	26	14	0.22	6
S.	23	13	0.24	6
SW.	16	9	0.22	3
W.	3	2	0.05	1
NW.	30	17	0.17	4
WINTER.				
N.	23	20	0.11	9
NE.	32	28	0.22	11
E.	11	9	0.21	7
SE.	17	15	0.13	9
S.	9	8	0.07	6
SW.	4	3	0.04	5
W.	1	1	0.04	3
NW.	19	16	0.15	9

The surface weather data forming the basis of this analysis cover the period of observations at Drexel from the winter of 1915–16 to the spring of 1923, inclusive. The averages for summer and autumn are therefore for a 7-year period, and those for winter and spring, for 8 years. Only measurable amounts of precipitation (0.01 inch or more) have been considered.

In the case of autumn, winter, and spring it is thought the graphs are not appreciably in error. However, for the summer season the graph should be considered as only approximate. For obvious reasons, such as thunderstorm frequency and weak pressure gradients, surface wind directions in summer are not always a reliable index to general pressure distribution. The discussion referring to the graphs will therefore be devoted mainly to the three colder seasons.

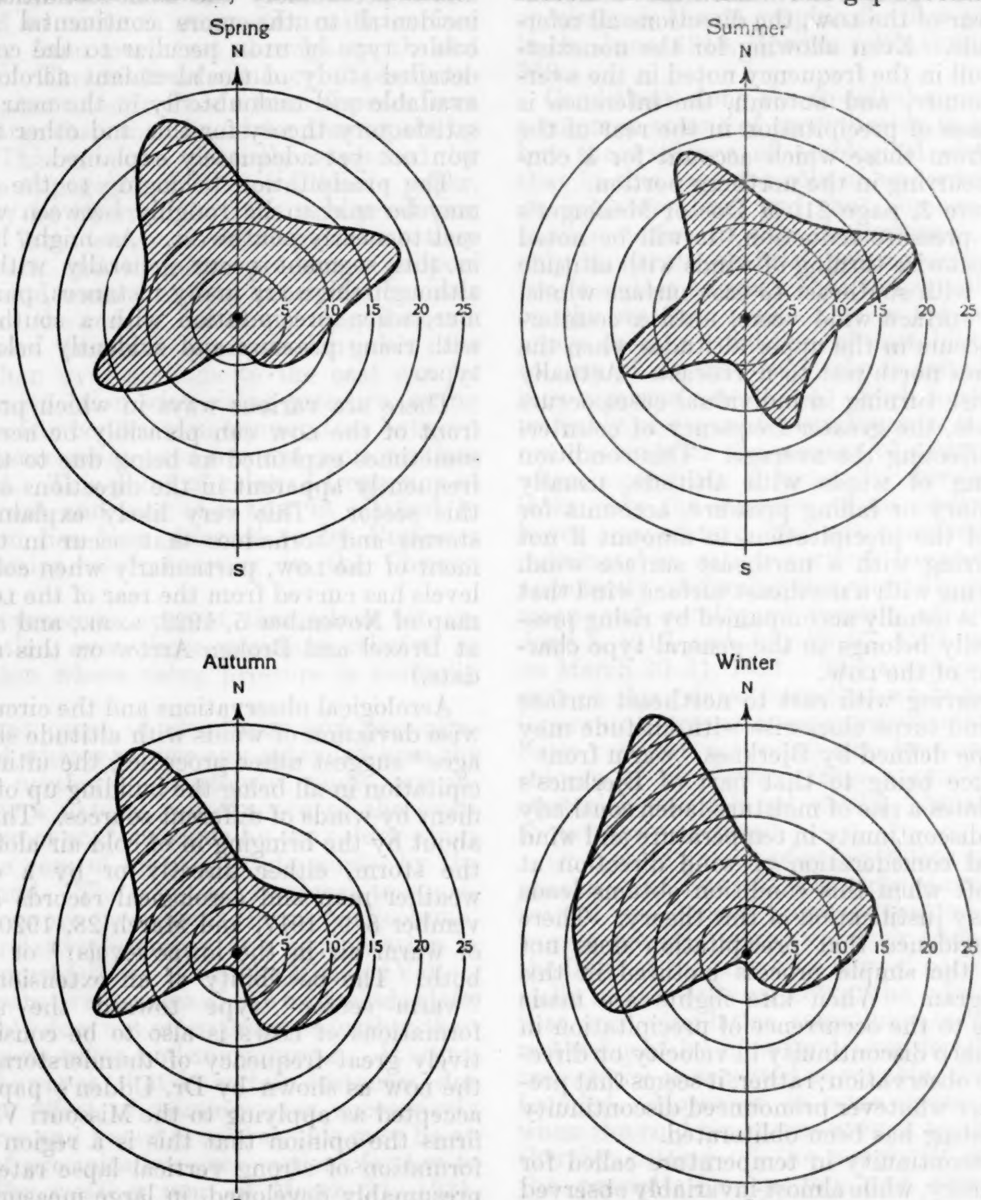

FIG. 1.—Graphical representation of third column, Table 1, showing in shaded area seasonal orientation of precipitation frequency about a center of low pressure. Figures on circles show frequency of precipitation in percentage of all observations for the season.

The main results of this statistical study, in so far as they relate to surface conditions, agree quite closely with those obtained by the late Dr. Anton D. Udden for Davenport, Iowa,[2] by a more laborious method. They show a maximum frequency of precipitation in the region north of the center of the LOW, although in summer this area is shifted more toward the east, if the summer graph is accepted without reservation.

There is a well-defined gap in frequency of precipitation in the southern portion of the circle, or the region of westerly to southwesterly winds, and another less pronounced gap in the northeastern portion, or region of easterly winds. The former is to be expected, both from the fact of uniform wind direction with altitude and dry sources of the wind. The gap revealed in the northeastern sector, hemmed in between two sectors of frequent precipitation, is of special interest, as the natural inference would be that the maximum frequency shown in the north should dwindle on both sides toward the south. The fact that this lull in frequency in the northeastern portion is apparent in the figures for all four seasons leads to the conviction that it is real, and not due to accident of observation or insufficient period of record. On the western side of the LOW there is considerable frequency of precipitation well down toward the south, although three of the seasonal means show a decided lessening in

[2] Udden, Anton D.: A statistical study of surface and upper air conditions in cyclones and anticyclones passing over Davenport, Iowa. MO. WEATHER REV., February, 1923, 51: 55–68.

frequency in the northwestern portion, and an increase again in the southwestern portion.

A justifiable conclusion from the foregoing is that in the Missouri Valley precipitation does not occur in a haphazard way about the center of the LOW, but that there are three rather distinct circumstances of position relative to the center that favor precipitation. For convenience these may be referred to as types, viz, (*a*) the region of south to southeast winds in the front of the LOW; (*b*) the region of east to northeast winds on the northern side of the LOW; and (*c*) the region of north-northeast to northwest winds in the rear of the LOW, the directions all referring to surface winds. Even allowing for the nonexistence of the gap or lull in the frequency noted in the averages for spring, summer, and autumn, the inference is strong that the causes of precipitation in the rear of the LOW are different from those which account for a considerable portion occurring in the northern portion.

Referring to Figure 2, page 21, of Doctor Meisinger's work on upper air pressure reduction,[3] it will be noted that the average clockwise turning of winds with altitude is at the maximum with southeast to east surface winds, diminishing as the surface wind veers, until a counterclockwise turning occurs in the upper altitudes when the surface wind becomes northwest to northeast. Actually the greatest clockwise turning in individual cases occurs with northeast winds, the greater frequency of counterclockwise turning affecting the average. This condition of clockwise turning of winds with altitude, usually attended by stationary or falling pressure, accounts for perhaps the most of the precipitation, in amount if not in frequency, occurring with a northeast surface wind. Precipitation occurring with a northeast surface wind that backs with altitude is usually accompanied by rising pressure, and undoubtedly belongs to the general type characteristic of the rear of the LOW.

Precipitation occurring with east to northeast surface winds where the wind turns clockwise with altitude may be placed in the type defined by Bjerknes "warm front" sector,[4] this reference being to that part of Bjerknes's theory which postulates a rise of moisture-laden southerly winds up a slope of discontinuity in temperature and wind direction. A casual consideration of wind direction at the surface and aloft when this condition obtains leads to an apparently easy justification of this theory. There is, however, some evidence that precipitation does not occur precisely by the simple process pictured in this "warm front" diagram. When kite flights are made during or very close to the occurrence of precipitation in this condition, no sharp discontinuity in velocity or direction is shown by the observation; rather, it seems that precipitation begins after whatever pronounced discontinuity in wind already existing has been obliterated.

Moreover, the discontinuity in temperature called for by the Bjerknes's theory, while almost invariably observed in the lower levels in the cold season, may be only incidental to the contrasts in temperature in the lower atmosphere, characteristic of continental winters. Certainly, latitudinal temperature differences must be the prime cause of this vertical arrangement of divergent winds and attendant precipitation, yet it seems doubtful that a sharply defined stratification in either temperature or winds is a necessary condition. The aerological observations made at Drexel on June 1, 1917, July 28, 1918, and August 26, 1922, are cited as a few specimens of records in support of this assertion. These observations represent quite well the vertical distribution of temperature in this type of precipitation in the warmer season, viz, an unbroken lapse rate (except near the ground) throughout the vertical column of air embraced by the observation. Reference may also be made to some upper air investigations on this subject carried out in England[5] from which the inference may be drawn that the presence of temperature discontinuites on the European Continent and the absence of them in England under presumably the same conditions may again be incidental to the more continental and consequently colder type of HIGH peculiar to the continent. A more detailed study of the abundant aerological records now available will undoubtedly in the near future result in a satisfactory theory for this and other types of precipitation not yet adequately explained.

The precipitation belonging to the front of the LOW may be said to lie roughly between winds from about east to nearly southwest. As might be expected, rains in this segment occur generally with falling pressure, although there are many instances, particularly in summer, when precipitation with a southwest wind occurs with rising pressure and evidently belongs to a different type.

There are various ways in which precipitation on the front of the LOW can plausibly be accounted for. It is sometimes explained as being due to the convergence so frequently apparent in the directions of surface winds in this sector. This very likely explains many thunderstorms and tornadoes that occur in the southeast segment of the LOW, particularly when cold air in the lower levels has curved from the rear of the LOW. (See weather map of November 5, 1922, a. m., and aerological records at Drexel and Broken Arrow on this and the preceding date.)

Aerological observations and the circumstance of clockwise deviation of winds with altitude shown by the averages [3] suggest other processes, the ultimate cause of precipitation in all being the building up of an adiabatic gradient by winds of different sources. This may be brought about by the bringing in of cold air aloft from the rear of the storm, either directly or by a curved path (see weather map and aerological records at Drexel on November 8-9, 1917, and March 28, 1920); the bringing in of warm air in the lower levels;[6] or a combination of both. The possibility of an extension of the so-called "warm sector" type toward the south in certain formations of LOWS is also to be considered. The relatively great frequency of thunderstorms in the front of the LOW as shown by Dr. Udden's paper, which may be accepted as applying to the Missouri Valley as well, confirms the opinion that this is a region favorable for the formation of strong vertical lapse rates in temperature, presumably developed, in large measure at least, by the processes just mentioned.

Comparing the graphs for the different seasons, the winter graph shows the smallest ratio of precipitation frequency in the south and southeast portion, compared with the north portion; in fact the precipitation at this season appears to be confined largely to the north and west portions. The logical inference from this winter orientation of precipitation relative to the center of low pressure, considered in connection with Mr. Gregg's

[3] Meisinger, C. L.: The preparation and significance of free-air pressure maps for the central and eastern United States. MO. WEATHER REV. SUPPLEMENT No. 21, 1922.

[4] Bjerknes, V.: On the structure of moving cyclones. MO. WEATHER REV., February, 1919. 47: 95-99.

[5] W. H. and L. H. G. Dines: An examination of British upper air data in the light of the Norwegian theory of the structure of the cyclone. *Quarterly Journal of the Royal Meteorological Society*. July, 1923, pp. 167-173.

[6] Jakl, V. E.: Some observations on temperature and winds at moderate elevations above the ground. MO. WEATHER REV., June, 1919. 47: 371.

tables of average latitudinal temperature gradients in the lower levels,[7] is that the winter precipitation over central sections of the country is largely due to warm air aloft passing toward the north, possibly in inclined paths, and to air forcibly raised by underrunning cold air near the ground. From the average winter temperature gradient,[8] the building up of an adiabatic gradient necessary for precipitation undoubtedly necessitates, for middle-northern regions, the transport of air over comparatively long distances.

Precipitation in the rear of a LOW or front edge of a HIGH may be said to occur in connection with surface winds all the way from northeast through north and west to southwest. The relative frequency of precipitation in the rear of a LOW and front of a HIGH appears from Table 1 to be greater than that found for Davenport by Doctor Udden. This may be partially explained by referring to Figure 4, page 57 of Doctor Udden's paper, from which it may be inferred that the rain producing lows are in some later stage of development as they approach Davenport, and therefore produce a proportionately greater and more frequent precipitation over portions other than the rear of the LOW. Also it seems plausible that more frequent precipitation over the Missouri Valley than over sections to the east can be accounted for in connection with rising pressure, owing to the generally greater contrasts in temperature between high and low pressure areas over western sections than farther to the east. This point of relative frequency of precipitation in front and rear of a LOW in relation to geographic position has been referred to by Professor Cox in his discussion of forecasting in the Chicago district.[9]

Three different processes suggest themselves for explaining precipitation over those positions relative to pressure distribution where rising pressure is normally to be expected.

(*a*) An important cause of cloudiness and precipitation is to be found wherever over any extended area the wind changes to northerly. Northerly winds are inherently turbulent, a natural consequence of the overrunning of the warmer surface winds by the colder winds aloft, aided in the case of lower altitude winds, by the friction of the ground. The result is a tendency to equalization of vapor pressure throughout the vertical column, from which high relative humidity and condensation in the upper portion must follow. Over the Missouri Valley, owing to the comparative dryness of the cold winds aloft, this process probably does not often progress further than the stage of cloudiness, mists, and snow flurries. It seems highly probable, however, that in certain instances, due to the cumulative effect of passing over successively higher temperatures and vapor pressures, this may be an important cause of precipitation over sections farther to the southeast. The weather map of March 21, 1921, shows an apparent example of this process causing precipitation just to the southeast of Drexel in the front of a HIGH that had passed over Drexel without causing precipitation.

(*b*) The precipitation assumed to be caused by the underrunning effect of colder currents, entails a process that can not easily be visualized satisfactorily in all its aspects, yet there are many instances that seem to admit of no other explanation. The Bjerknes diagram and its "narrow stripe" rain, or, "squall line" does not explain all the precipitation apparently due to underrunning cold air that occurs in this country, particularly in the colder seasons. A better idea of the three-dimensional structure of air under these conditions may be obtained by reference to Figure 31 and Chart XVIII of Doctor Meisinger's paper. Figure 31 shows a common structure of lows;[10] and Chart XVIII an apparent application of this structure to the formation of precipitation in the rear of a LOW on December 9, 1919.

Aerological observations made in pronounced cases of underrunning cold currents show the wedge-shaped altitude-temperature curves typical of cold waves. A specimen is shown graphically in a paper by V. E. Jakl, in the June, 1919, MONTHLY WEATHER REVIEW, on page 369.

Conditions along the so-called squall line appear to be a common source of precipitation in the warmer months, but the evidence of aerological observations indicates that in this case the rôle of underrunning winds is only an initiatory one, and that copious precipitation with thunderstorms in this circumstance often results from only moderate or brief pressure rises, since frequently the trough is so weak that the squall line is not defined on the weather map. One is led to conclude that in many cases a condition of instability is built up in a column of air that lacks only an initial impulse to develop into vigorous convection. Such a sequence of events is probably of common occurrence in the warmer season in connection with the passage of a trough of low pressure, where a condition of instability develops in the front, but lacks only the stimulus of an underrunning current of lower temperature, but not necessarily great depth, to culminate in active vertical convection. Illustrations, apparently confirming this view, are given by the weather maps and aerological records at Drexel on May 30–June 1, 1919, and July 25–27, 1921, and at Royal Center on March 30–31, 1921. The aerological and surface records on these dates show that while high humidity and a lapse rate in temperature approximately equal to the adiabatic rate for saturated air developed in the vertical column of air flowing from a southerly direction, precipitation was delayed until a "break" or shift in wind to northerly occurred.

(*c*) A third process of precipitation in regions of expected pressure rise, but which is perhaps confined strictly to the rear of well-defined LOWS, is that which can be inferred from a possible transport of air from the lower levels in the front of the LOW by a curved path to the rear. Especially in slow-moving LOWS, the inference is unavoidable that such circulation sometimes takes place, and if the method used by Shaw and Lempfert[11] for tracing surface trajectories is accepted as reliable, the assumption is well founded. Moreover, in some instances it is noted that when the cold air curves around to the front of the LOW, thereby cutting off the supply of warm southerly air, the precipitation in the rear ceases. (See maps of November 4–5, 1922.)

The passage of air into a region potentially colder than itself, especially when it presumably curves to the rear of a LOW, is more easily imagined than explained with a full cognizance of the dynamics of the problem involved. Undoubtedly considerable force, realized from the pressure gradient, is expended in accomplishing this result. The possibility of air rising as it approaches a colder region is also to be considered. Air that has escaped

[7] [8] Loc. cit., pp. 10 and 36–47, respectively.

[9] Weather forecasting in the United States, p. 299.

[10] In the opinion of the writer this displacement of the trough of low pressure with altitude is a function of the shape of the trough as well as the season of the year. It is strongly characteristic of elongated, crescent, or trough shaped lows, a point brought out by the writer on p. 246, MO. WEATHER REV., May, 1922, in a report on the "Meteorological Aspects of the Thirteenth National Balloon Race."

[11] Shaw and Lempfert: The life history of surface air currents. London, 1906.

ascent successively on the east and north sides of a LOW may reasonably be supposed to be constrained to rise after reaching the rear, as it must necessarily overrun the air of lower temperature fed into the LOW from the rear. For similar reasons air that has already risen on the east or north sides of a LOW may reach the rear and continue to rise. In this connection reference is made to the weather maps of October 27, 1918, and November 29, 1919, where, so far as surface maps may be taken as evidence, the circumstance of precipitation in the rear of a LOW, where the pressure was actually falling, indicates the possibility of air being forcibly drawn from the front to the rear of the LOW. On both maps it will be noted that the usual rise in temperature in the front of the LOW has extended well to the north of the LOW.

Of these two dates, aerological records are available for November 29, 1919, from Drexel and Broken Arrow, Okla., the observations at both stations having been taken near the ending of the precipitation. An approximately isothermal state to 2,400 meters, and a moderate lapse rate thereafter to 3,500 meters, is shown in the vertical column over Drexel, while over Broken Arrow a pronounced lapse rate is shown to 1,800 meters and an inversion immediately above. The temperatures were the same at 1,800 meters over Drexel and Broken Arrow. The lower limit of altitude at Drexel at which precipitation had occurred and to which surface air from around the front and north of the LOW had been transported is probably defined at about 2,400 meters. Over Broken Arrow, which was then in the southwest portion of the LOW, precipitation is explained by the adiabatic gradient extending from the ground upward. This gradient probably extended above 1,800 meters earlier in the storm, as a second observation made on the same date showed rising temperature aloft.

A significant fact in connection with the generally greater and more frequent precipitation in spring than in autumn, is the spring upper-air temperatures as shown by the averages.[8] The lag in the recovery of temperature aloft in spring is shown by the temperature records for all northern aerological stations for March and April, and a month earlier for the southern stations. It is graphically shown for Drexel in Figure 2, page 3, MONTHLY WEATHER REVIEW, January, 1920.[12] This fact was alluded to by the writer in a previous paper [13] as indicating conditions of instability in certain circumstances of spring weather. A statistical study might show a preponderance of Pacific HIGHS at this time of year, the Pacific HIGHS showing a greater average vertical lapse rate in temperature than do those of northern origin.

[12] Gregg, W. R.: Average free-air conditions as observed by means of kites at Drexel Aerological Station, Washington, Nebr., during the period November, 1915, to December, 1918, inclusive. Mo. WEATHER REV., January, 1920, 48: 1-11.

[13] Jakl, V. E.: A kite flight in the center of a deep area of low pressure. Mo. WEATHER REV., April, 1920, 48: 198-200.

PILOT-BALLOON OBSERVATIONS AT SAN JUAN, PORTO RICO.

By OLIVER L. FASSIG, Meteorologist.

[Abstract of an informal talk before the Weather Bureau staff meeting, Washington D. C., of January 9, 1924.]

Doctor Fassig, who is in charge of the Weather Bureau service in the West Indies, presented to the Weather Bureau staff on his recent visit to Washington, D. C., a summary of the results of pilot balloon observations made at San Juan, P. R., under his supervision during the four hurricane seasons of 1920, 1921, 1922, and 1923.

San Juan, as explained by Doctor Fassig, is favorably situated with respect to the conduct of pilot balloon work. The station is well within the northeast trade region of the North Atlantic and the sky conditions are such that an ascent to 4 or 5 kilometers can be made on about 90 per cent of the days. The trades carry the balloon in a westerly direction until it reaches the so-called antitrades of the levels above 5 or 6 kilometers; it is then carried back over the observing station almost directly overhead.

A diagram was presented showing the wind direction for each day from August 29 to October 2, 1923. On nearly 50 per cent of the days the balloons reached an altitude of 10 kilometers or over. The diagram is reproduced as Figure 1.

This diagram clearly shows that in the lower levels, up to at least 4 kilometers the winds were uniformly from an easterly direction. Occasionally, as on August 13-15 and again on August 29-30, reversals set in above the 3 kilometer level and continued for a day or so. Sometimes these reversals extend to the surface, but in the 1923 season there was but a single westerly wind observed at the surface, viz, that on August 29. The gradient at times of reversal must be very weak, since at levels above about 6 kilometers easterly and westerly winds occur nearly in equal proportion—see the period August 13-21. On rare occasions the west winds form a solid current up to the top of the ascent, on one occasion in the season of 1922 a solid SW. wind was observed from 3 to 13 kilometers.

The average wind velocity.—The inset on Figure 1 shows the average wind velocity for each month of the year from the surface up to the highest point reached. The averages for January to May, inclusive, and for December, are based upon a single year's observation, the remaining months are based on 4 years, except that June is for but 3 years. For so short a period the curve is a remarkably uniform one, with two pronounced maxima and two minima.

The group of wind roses in Figure 2 on the right shows the wind direction and frequency, in percentages, for the levels, surface up to 10 kilometers.

The curve in the center of the figure represents the average wind speed in m. p. s. all months and levels, surface up to 14 kilometers. Above that level the observations were not plentiful enough to yield a reliable average. The wind roses on the left show the direction and average speed of the wind in meters per minute up to 9 kilometers for a single season only. The wind roses on the right are also for a single season.

On October 2, 1923, a pilot balloon was observed continuously for 186 minutes. The trajectory of the balloon is shown in Figure 3. Assuming a rate of ascent of 180 meters per minute the elevation reached by this balloon must have been more than 33 kilometers. Since Doctor Fassig had some misgivings as to the accuracy of this result, he submitted the data of the ascent to the aerological investigations branch of the Central Office of the Weather Bureau for comment. The discussion that followed is given in full below. It is hoped to present a detailed discussion of the San Juan pilot balloon ascent in the near future.—*A. J. Henry.*

DISCUSSION.

By W. R. GREGG and W. C. HAINES.

The results of pilot balloon observations at San Juan are of great interest, since they constitute a fund of information concerning free-air conditions in a region in which little work of the kind has heretofore been carried on. Their value is great or small in proportion as they can be shown to be truly representative of actual conditions. Aside from the usual limitations to which observations with balloons are subject, viz, absence of clouds in the lower levels, good visibility, and moderate wind speeds, there is in the present case the added uncertainty as to the conformity of the actual rate of ascent to the assumed rate.

Theoretically we should expect a balloon to rise at a rate inversely proportional to the sixth root of the density.[1] For summer time conditions in this country,

[1] Cave, C. J. P.: The structure of the atmosphere in clear weather, p. 4, 1912.

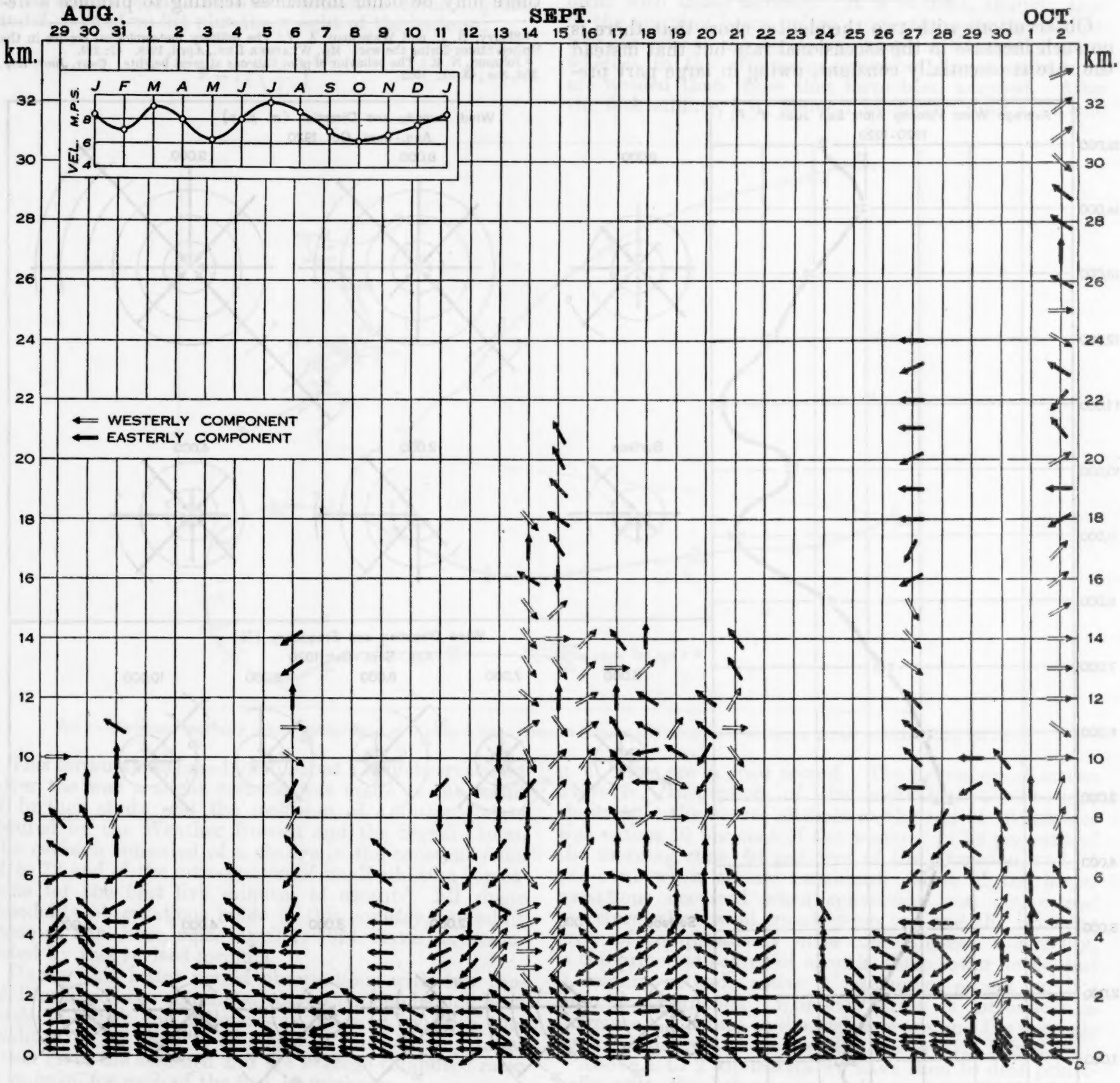

FIG. 1.—Wind direction at various elevations at San Juan, P. R., Aug. 29-Oct. 2, 1923. Inset: Average wind velocity for each month from surface to highest elevation attained at San Juan, P. R., January to May, inclusive, and December based on one year's observations, June on 3 years, and remaining months on 4 years.

approximately those prevailing at San Juan, this would give the following average rates of ascent, calling that at the surface unity:

Altitude.	Density.	Rate of ascent.
km.	*g/m.*^{3}	
0	1.175	1.000
5	.723	1.084
10	.418	1.188
15	.209	1.333
20	.095	1.521
25	.048	1.704
30	.023	1.926

Observations with two theodolites show that there is no such increase in the ascensional rate but that instead the rate is essentially constant, owing in large part presumably to the counteracting influence of diffusion through the rubber envelope. We do not know the extent of this diffusion as the balloon rises, but with a balloon inflated for an ascent the rate has been found to be about 4 to 6 per cent of the volume per hour,[2] with little change in the rate during the first 4 hours.[3]

Computation for an average weight balloon, inflated to ascend at 180 m./min., the rate of diffusion being assumed as 6 per cent, gives 227 m./min. as the ascensional rate at 15 kilometers, or 1.261 times the initial rate as against 1.333 shown in the table. Evidently, then diffusion increases rapidly as the balloon expands, though there may be other influences tending to produce a de-

[2] Sherry, B. J., and Waterman, A. T.: The military meteorological service in the United States during the war. MO. WEATHER REV., April, 1919. 47: 219.

[3] Johnson, N. K.: The behavior of pilot balloons at great heights. *Quar. Jour. Roy. Met. Soc.*, 48: 53. 1922.

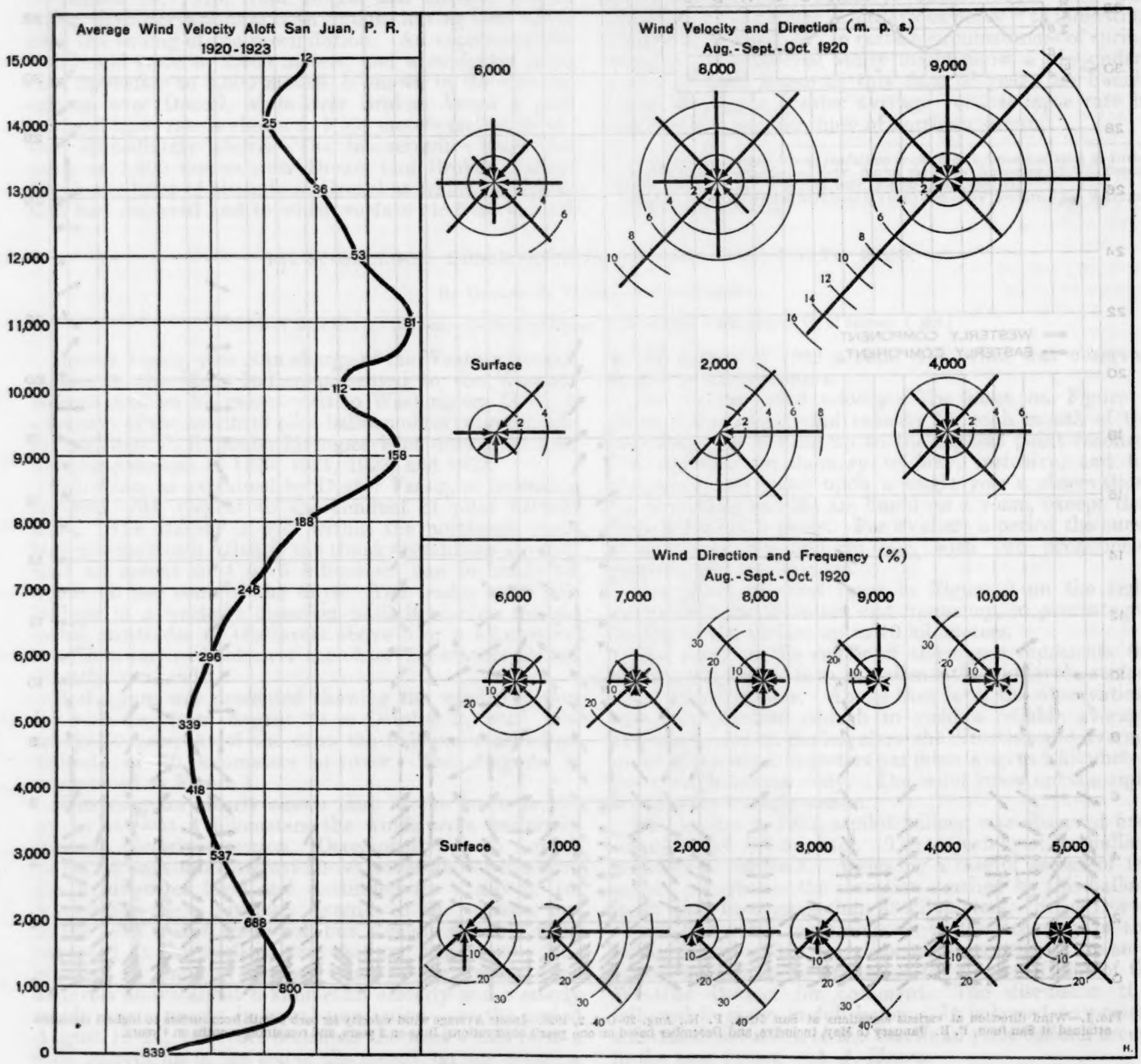

FIG. 2.—Left: Average wind velocity, surface to 15 kilometers, at San Juan, P. R., 1920-1923. (Number of observations upon which average is based indicated along the curve.) Upper right: Average wind velocity and direction at several elevations for autumn, 1920, at San Juan, P. R. Lower right: Percentage frequency of winds from different directions, autumn, 1920, San Juan, P. R.

creased rate, such as the effect of low temperatures on the elasticity of the rubber. The only way in which these factors could be evaluated would be to place a balloon in an altitude chamber and subject it to pressure and temperature conditions similar to those through which it passes during actual ascents. Even then only a rough approximation could probably be realized.

In the absence of such tests it has been necessary to resort to the results of double theodolite observations. This was done during the war by the officers of the United States Signal Corps,[4] and the following empirical formula was developed, in which V is the rate of ascent in m./min., 1 is the free lift or ascensional force in grams and L is the free lift plus the weight of the balloon:

$$V = 71 \left(\frac{l^3}{L^2}\right)^{.208}.$$

	1	2	3	4	5	6	7	8	9	10
Assumed	216	198	198	189	189	180	180	180	180	180
a. m. (292)	204	185	181	181	182	181	180	183	180	181
p. m. (513)	222	206	204	197	191	185	184	182	183	183
a. m. and p. m. combined (805)	216	197	196	190	187	184	182	182	182	181

The a. m. observations are ordinarily taken between 7 and 8, and the p. m. between 3 and 4. Figures in brackets give the number of observations on which the means are based.

The mean rates for all observations show striking agreement with those assumed. It is evident, though, that in the morning hours before convection sets in no additive corrections are necessary except in the first minute, whereas in the afternoon somewhat larger corrections are needed than those that have been adopted. After the fifth minute, i. e., above 1 kilometer, both a. m. and

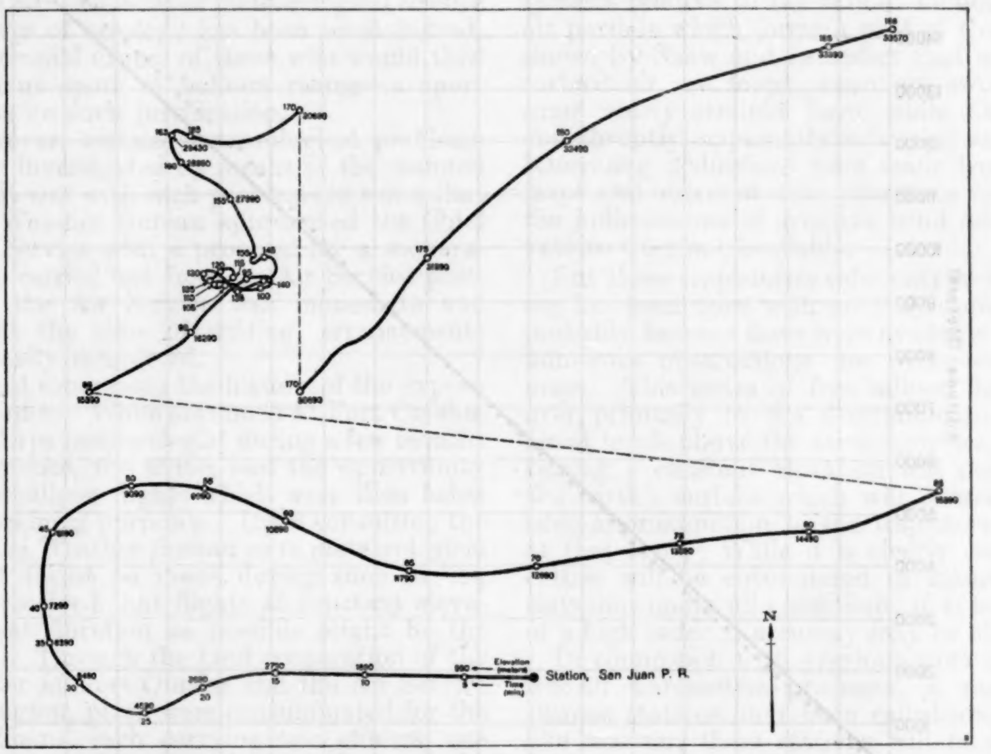

FIG. 3.—Horizontal trajectory of pilot balloon flight of October 2, 1923. Time in minutes and elevation of balloon in meters indicated along the curve.

This formula was based upon about 1,000 observations. After the war a slight revision was made as the result of further study and the inclusion of additional data secured by the Weather Bureau and the Signal Corps. The revision consisted of a change in the constant from 71 to 72 and of the introduction of small additive corrections for the first five minutes of ascent.[5] All single theodolite observations made in this country, including those at San Juan, since April 1, 1921, have been computed by this revised formula.

During this latter period observations with two theodolites have been continued, more than 800 having been made in which the balloon was followed by both theodolites for 10 minutes or longer. The following tabulation gives the assumed and the average computed rates in m./min. for each of the first 10 minutes:

p. m. rates are in good accord. The figures are of course averages. Inspection of the individual observations shows that the actual altitude at the end of 10 minutes was within 10 per cent of the assumed in 99 per cent of the morning runs, 64 per cent of the afternoon, and 75 per cent when all are combined. Most of the larger variations occurred when convection was active and therefore when wind speeds were low and the resulting error of comparatively little consequence. Convection is the principal source of error in these lower levels, but it seldom extends above 2 kilometers except on hot summer afternoons. Whatever error it introduces is therefore a constant in the higher levels and the percentage of error from this cause diminishes with height.

Above 1 to 2 kilometers we have then to deal principally with the behavior of balloons in still air (i. e., "still," in a vertical sense). The 805 observations that have been considered extended to various heights above 2 kilometers, some 50 of them reaching 10 to 15½ kilo-

[4] Sherry, B. J., and Waterman, A. T.: *Loc. cit.*, p. 218.
[5] Sherry, B. J.: The rate of ascent of pilot balloons. MO. WEATHER REV., December, 1920. 48: 692-694.

meters. Almost without exception the ascensional rates between 2 and about 10 kilometers were essentially constant. Above 10 kilometers, however, there is evidence of an increase in the rate. A typical, and also thus far the highest, observation is shown in figure 4, in which the broken curve represents the time-altitude relation in a double theodolite run at Groesbeck, Tex., on the afternoon of August 24, 1923, and the straight line gives the assumed rate. Up to 10 kilometers the two lie close together, but above that height there is a gradual falling apart. Even so, the error at the greatest height reached is not quite 5 per cent, the actual height being 15,360 meters as against an assumed value of 14,670. Whether or not this departure from a constant rate continues or perhaps increases at greater heights is not known.

2. In individual observations the actual heights at the end of 10 minutes, about 2 kilometers, are within 10 per cent of the assumed in about three-fourths of all cases, the largest departures occurring when convection is active and therefore when horizontal air movement is slight and the error of small consequence. Observations taken in the morning hours are correct within 10 per cent in practically *all* cases.

3. At heights between 2 and about 10 kilometers the accuracy is still greater, since convection is ordinarily absent at these levels and the balloons ascend at essentially a constant rate, very close as a rule to the assumed rate.

4. From 10 to 16 kilometers the rate increases gradually and assumed heights are 5 to 10 per cent too small at 14 to 16 kilometers.

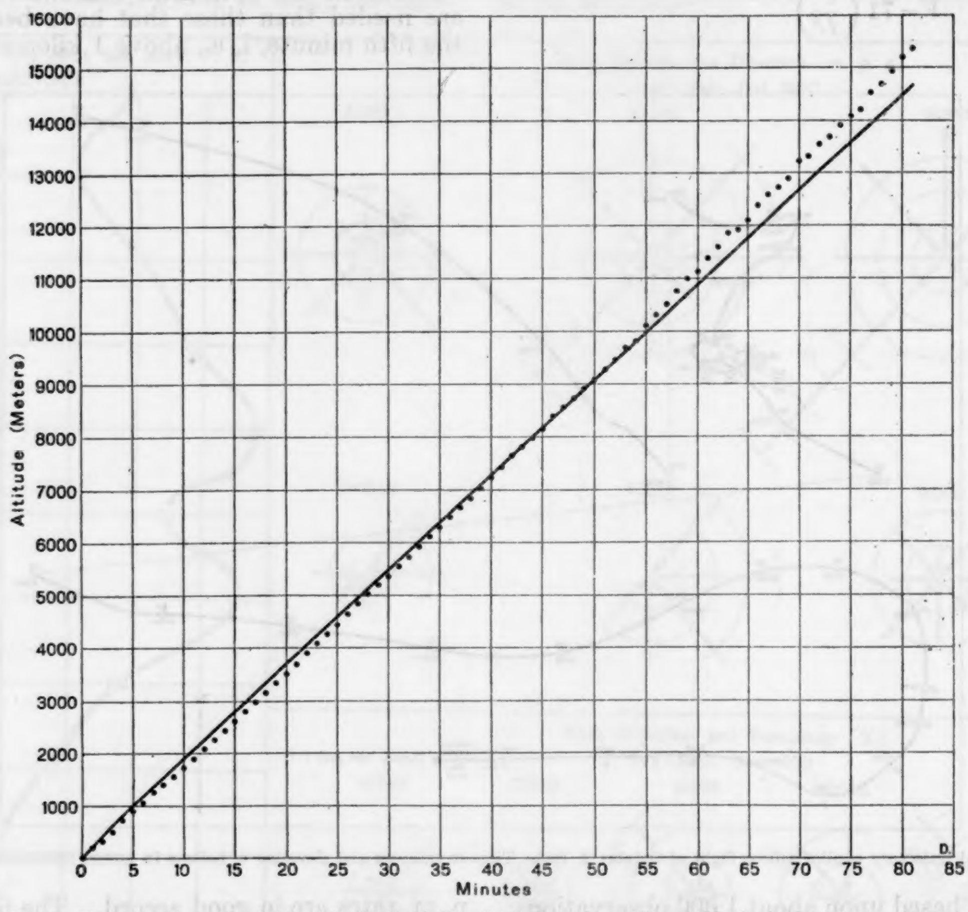

FIG. 4.—Time-altitude graph of highest double-theodolite pilot-balloon observation at Groesbeck, Tex., August 24, 1923.

Efforts are being made, whenever opportunity offers, to obtain double theodolite observations to as great heights as possible and it is hoped that more light on this question will soon be available.

It is worthy of note that of the 805 cases examined only one, or possibly two, showed evidence of a slow leak caused by pinholes. Not a single case was found in which the balloon reached a state of equilibrium and floated. As a rule observations ended because of the bursting of the balloons or disappearance on account of distance, haziness or clouds.

CONCLUSIONS.

1. On the average there is striking agreement between the assumed and the actual heights at all levels from the surface to about 10 kilometers.

5. As to what takes place above 16 kilometers we have at present no information. It seems likely, though, that the best balloons continue to rise to perhaps 20 or 25 kilometers, and that the rate of ascent increases considerably.

6. So far as observations at San Juan are concerned, it seems reasonable to conclude: (*a*) That mean values are essentially correct; (*b*) that individual observations, since they are made in the morning hours, are correct within 10 per cent in the lower levels and within 5 to 10 per cent at heights between 2 and 15 kilometers; and (*c*) that at heights above 15 to 16 kilometers nothing definite can be stated at present as to their dependability.

A more detailed study of the general problem of behavior of pilot balloons is in preparation.

THE BALLOON PROJECT AND WHAT WE HOPE TO ACCOMPLISH.[1]

By C. LeRoy Meisinger.

[U. S. Weather Bureau, Washington, D. C., Feb. 20, 1924.]

In times past, the manned free-balloon has been extensively used for the collection of meteorological information. One needs but to look at the ponderous *Wissenschaftliche Luftfahrten* of Assmann and Berson to appreciate the elaborateness with which some of these experiments were carried out. But such efforts were directed largely toward the measurement in the vertical of meteorological elements such as temperature and humidity, and these can now be made regularly and frequently by means of kites and sounding balloons under much more satisfactory conditions of instrument exposure, and certainly at much smaller expense. Free ballooning in the interest of science, therefore, has not been extensively practiced in recent years; and the contribution of the free balloon to the advancement of meteorological science since the early days of aerology has been scant indeed, in spite of the perennial claims of those who would thus justify the excellent sport of balloon racing—a sport which really needs no such justification.

There are, however, certain meteorological problems which can best be investigated by means of the manned free balloon, and it was with such problems in mind that the Chief of the Weather Bureau approached the Chief of the Army Air Service with a proposal for a cooperative project to be carried out from an Air Service post. The response of the Air Service was immediate and favorable, and, at the time of writing, arrangements have been practically completed.

History.—A word concerning the history of the experiment may be in order. While stationed at Fort Omaha, Nebr., as Signal Corps meteorologist during a few months following the armistice, the writer had the opportunity to engage in free-balloon flights which were then being made chiefly for training purposes. Upon consulting the Central Office of the Weather Bureau as to meteorological observations that might be made during such flights, information was received that flights at constant elevations of as great duration as possible might be the best contribution. Through the kind cooperation of the commanding officer at Fort Omaha and the Air Service officials in Washington, plans were consummated for the flight of two balloons, each carrying two officers, one balloon to maintain an elevation of 10,000 feet and the other 5,000 feet for as long a time as possible. The full moon, riding in the clear sky of the night of April 16, 1919, saw the getaway of these two balloons, and the bright afternoon sun of April 17 saw the lower one land at Cabot, Ark., and the higher land at Arcola, Miss.[2]

Circumstances were not auspicious for the carrying out of further long flights of this character at that time, but, with his discharge from the Army and his assumption of duties in the Weather Bureau at Washington, the writer has cherished with undiminished enthusiasm the desire to make a series of such flights, carefully planned to take advantage of selected weather types and to utilize to the fullest extent synchronous observations at the surface and in the free air. The time seems now to be propitious for this effort.

Scott Field, Belleville, Ill., has been designated as the post from which the flights will be made, and a qualified pilot has been assigned by the commanding officer to the duty of collaborating with the Weather Bureau's representative in carrying on the work. The flights, of which it is hoped to make approximately 15, will start about April 1.

Free-air trajectories.—Meteorologists are familiar with the interesting trajectories of surface air deduced by Shaw and Lempfert in their studies of wind movement in relation to barometric situations in and about the British Isles.[3] These trajectories clearly showed that our conception of the circulation about centers of low and high pressure, based solely upon the instantaneous stream lines and synchronous wind arrows of the daily weather map, may be quite erroneous if the pressure systems are not stationary. Much depends, therefore, upon the rate of translational motion of the isobaric systems relative to the rate of motion of the individual air particle which forms a part of that system. It was shown by Shaw and Lempfert that some trajectories of surface air are loops, some are sweeping curves, and some nearly straight lines, while many converge and end abruptly, apparently indicating ascent of air. These interesting deductions were made from hourly pressure maps and observed wind directions in combination with the judicious use of gradient wind relations when observations were not available.

But those trajectories refer only to surface air. Nothing has been done with air trajectories at higher levels, probably because there were available neither sufficiently numerous observations nor synoptic free-air pressure maps. This series of free-balloon flights will be given over primarily to the determination of trajectories of air at levels above the earth's surface. A balloon maintaining a constant elevation will describe a path over the earth's surface which will constitute the best possible approximation to the trajectory of an air particle at that level. While it is clearly recognized that difficulties will be encountered in maintaining a constant elevation under all conditions, it is believed that results of a high order of accuracy may be obtained.

In connection with previous work in the reduction of free-air barometric pressures, a number of Weather Bureau stations have been called upon to assist.[4] In a like manner, these stations will be asked to carry on daily pressure reductions to free-air levels throughout the period of these flights. The free-air maps thus made available will make possible comparisons between observed and theoretical trajectories, and, perhaps, permit us to know what degree of confidence we may legitimately have in conclusions regarding free-air movements based solely upon the maps.

Recent studies in the mechanism of cyclones and anticyclones, such as the kinematical investigations of Kobayasi[5] and Ryd,[6] and the dynamical studies of Bjerknes,[7] have served to emphasize the great and immediate necessity for observations as to the nature of air trajectories at various levels in cyclones and anticyclones.

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[1] Presented before the Weather Bureau Staff at its meeting of Feb. 20, 1924.

[2] Meisinger, C. Le Roy: The constant-elevation free-balloon flights from Fort Omaha. Mo. Weather Rev., August, 1919, 47: 535-538.

[3] Shaw and Lempfert: The life history of surface air currents. *M. O. No. 174*, London, 1906.

[4] Cf. Meisinger, C. LeRoy: Concerning the accuracy of free-air pressure maps. Mo. Weather Rev., April, 1923, 51: 190-199.

[5] Kobayasi, T.: On the mechanism of cyclones and anticyclones. *Quarterly Journal of the Royal Meteorological Society*, July, 1923, pp. 177-189.

[6] Ryd, V. H.: Travelling cyclones. *Publikationer fra det Danske Meteorologiske Institut, Med. Nr. 5*, Copenhagen, 1923.

[7] Bjerknes, V.: On the dynamics of the circular vortex with applications to the atmosphere and atmospheric vortex and wave motions. *Geofysiske Publikationer*, Vol. II, No. 4. Christiania, 1921.

Trajectory determinations.—It is apparent that the success of these observations is largely dependent upon the accuracy with which the momentary position of the balloon can be determined. This may be accomplished in any or all of three ways. First, without clouds below the balloon, it is a relatively easy matter to ascertain one's position by comparison of topography with reliable maps. Even on dark nights, cities and towns, streams and railroads, and other landmarks are quite easily distinguishable. When clouds obscure the land below but heavenly bodies are visible above, the position of the craft can be quite accurately determined by the usual methods of navigation, using an aircraft sextant with bubble horizon.[8] Such sextant observations should be quite satisfactory when made from a balloon, since this type of craft is relatively free from accelerations and decelerations to which an airplane is constantly subjected and which have so marked an effect upon the bubble horizon, and, consequently, upon the accuracy of the position determination. Finally, under any conditions of uncertainty as to location, bright-colored cards, conspicuous when lying on the ground, may be dropped. These may be printed in bold-faced type, addressed and franked, and the finder is asked to tell simply his name and the place and time of finding the card. He is requested to drop the card in the nearest mail box. In the case of the flight from Omaha mentioned earlier, about one-third of the cards dropped were returned. They were slightly weighted with small pieces of lead so as to increase the rate of fall and, consequently, reduce the amount of drift. The wisdom of this was shown in the good agreement between the known path of the balloon and the points where the cards were found, even when the cards were dropped from 10,000 feet.

Flights at other than constant elevations.—Not all the flights will be made at constant elevation. Some will be made with a view to taking advantage of over and under running winds. An attempt will be made to map out in advance as nearly as possible the desired barometric conditions in which the flights should be made, and then, as such conditions appear, take advantage of them so far as we may be able. Much will depend, therefore, upon the liaison that must be maintained by telegraphy and radio telephony between the forecaster at Washington and the balloonists.

Relations between forecasters and balloonists.—This liaison, as at present contemplated, will work in somewhat the following manner: The balloonists, having reported to the Washington forecaster their return to the field from the previous flight, and having indicated their availability for the next flight after a certain time (this being dependent upon availability of balloon and equipment and to some degree upon physical fatigue), the forecaster observes upon the weather map the approach of conditions suitable for carrying out a certain phase of the experiment and wires this advice to the balloonists who prepare promptly to act upon it. Just before taking off, a telegram is dispatched to Washington indicating the time of take-off and certain radio broadcasting stations which will be listened to at prescribed times for the reception of weather bulletins and further meteorological advice gleaned by the forecaster from the latest weather map which shall have been constructed since the take-off. A brief description of the map will make possible the construction in the balloon of an approximate copy for the study of the balloonists. If the balloon is yet in the air 12 hours after the first bulletin certain other broadcasting stations will be listened to for additional reports. Immediately upon landing, the Washington office will be notified of the fact, and the contemplated time of availability for the next flight. This is the cycle of anticipated communications between forecasters and balloonists.

Collection of dust samples.—There are several kinds of observations that can be made during the flights. One is upon the dustiness of the atmosphere as determined by the Owens' Dust Counter.[9] The record is obtained by drawing a known volume of saturated air through a narrow slit by means of an air pump. The condensation thus produced upon dust particles causes them to adhere to a microscope cover glass firmly placed just behind the slit. The water evaporates shortly after the glass is removed from the instrument and a line of dust is left behind. Dust counts are made with a microscope after the cover glass has been mounted in the usual manner upon a slide.

Measurements of sky brightness.—Photometric observations by means of the Holophane lightmeter[10] are contemplated. This instrument is of light weight, is compact, and is, therefore, well suited to use in aircraft. The sky is directly observed through a small elliptical diaphragm and its brightness is matched by a standard electric lamp. The lamp, which illuminates a larger concentric ellipse and which may be moved forward or backward by a tangent screw, operates at a specified voltage by means of an attached rheostat. The scale reads directly in foot candles and these units may readily be converted into millilamberts, units of brightness. Such brightness measurements are contemplated for specific points in the unclouded, or uniformly clouded, sky, at various elevations of the balloon.

Size of cloud droplets.—It was anticipated, also, that some measurements might be made upon the angular diameter of coronæ formed about a small, but bright, electric light when passing through clouds. This is a diffraction effect, and if the angular diameter were measurable, it would be related in a known manner to the diameter of the intervening cloud droplets. The success of such measurements seems to depend upon the uniformity of size of the droplets and the brightness of the light, and it is also essential that the light impinge upon the particles in a roughly parallel manner. A thin cloud of lycopodium powder blown into the air between the observer and the light near the observer yielded brilliant coronæ to the fourth order, but, in viewing the light through a thin cloud of steam the corona of the first order was observed but faintly, and much too faintly for accurate measurement. It is to be inferred either that the light was not sufficiently bright (although a lamp of small filament operating at considerable overvoltage was used), or the steam particles were of nonuniform size. In any case, the lack of complete success in preliminary experiments makes it advisable to hold this effort in reserve and continue experiments actually in the clouds.

Other instrumental equipment.—As a part of the instrumental equipment an Assmann aspiration psychrometer will be carried as well as the barograph element of a kite meteorograph. The object will be to keep an accurate

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[8] Eaton, H. N.: Aerial navigation (Pt. II), *U. S. Air Service*, October, 1923, pp. 39-44. *Also* abstract entitled *Air navigation*, by J. P. Ault, *Journal of the Washington Academy of Sciences*, Aug. 19, 1923, pp. 334-335.
Hunt, F. L.: Aeronautic instruments. *Technologic Paper of the Bureau of Standards*, *No. 237*. Pp. 493-497.

[9] A description, together with a photograph, of this instrument and an account of its use in collecting dust samples during airplane flights will appear in a later number of the REVIEW.

[10] *Transactions of the Illuminating Engineering Society*. Vol. XV, No. 8, 1920.

record of the temperature as indicated by a ventilated thermometer and of the pressure as recorded by a sensitive and carefully calibrated barograph. These two elements, in combination with the surface temperature and pressure will enable one to compute the altitude of the balloon and thus check its altitude against that indicated by the altimeter. A camera will probably be carried also, and photographs of clouds obtained whenever opportunity affords.

Conclusion.—This short discussion indicates briefly what it is hoped to accomplish during the balloon flights. While it is believed that this program can be quite closely adhered to, it should not be forgotten that in undertakings of this character unanticipated difficulties may arise to interfere more or less with the orderly prosecution of the work. The final report of the flights will indicate the degree of success enjoyed in this attempt at scientific ballooning.

A METHOD FOR LOCATING THE DECIMAL POINT IN SLIDE-RULE COMPUTATION.

By NELSON W. HAAS.

[Weather Bureau, Washington, D. C., Jan. 14, 1924.]

The slide rule has come to be, in rapid computations in the field and elsewhere, what logarithms are in more refined computations. In several branches of the work of the United States Weather Bureau the slide rule is used extensively, particularly in the Aerological Division in the work of which the slide rule is used exclusively for many purposes; in the computation work of single and double theodolite observations, the computation of mean wind velocities and directions at various altitudes above sea level, in the reduction of the aerological data from kite flights to various levels, etc. Twenty-inch slide rules are used chiefly for such computations. The slide rule is particularly well adapted to this work, for the 20-inch rule yields three figures accurately and the fourth approximately. Four figures represent the maximum accuracy that is readily attainable in meteorological observations, and consequently the 20-inch rule is entirely satisfactory for this work, and it is very expeditious.

In many of these computations the approximate magnitude of the result is already known. This still further expedites the computations, but in the general use of the slide rule, especially when there are several factors involved in the computation, difficulty or delay is often encountered in locating the position of the decimal point in the result.

The usual method of locating the position of the decimal point in a result obtained on the slide rule is by guessing at it, or by a mental approximation. The derivation of the various rules given in slide-rule manuals for this purpose is not immediately obvious, and so these rules must be retained by sheer memory. To my knowledge they are never used. The method outlined below I have found to be the quickest and to involve the least mental effort of any I have tried. The method is very simple to use, but the derivation of it is somewhat tedious.

To multiply two numbers together, their logarithms are added, and the characteristic of the logarithm of the product will equal the sum of the characteristics of the logarithms of the factors unless the sum of the mantissas is greater than 1, in which case 1 will be carried over from the mantissa of the sum to the characteristic. Likewise, in dividing one number by another, the characteristic of the logarithm of the quotient will equal the characteristic of the logarithm of the dividend minus the characteristic of the logarithm of the divisor unless the mantissa corresponding to the divisor is greater than the mantissa corresponding to the dividend, in which case 1 will be borrowed from the characteristic corresponding to the dividend. It is thus evident that the characteristic corresponding to a product is equal either to the sum of the characteristics corresponding to the factors, or to this sum plus 1; and that the characteristic corresponding to a quotient is equal either to the difference of the characteristics corresponding to the factors, or equal to this difference minus 1.

On the slide rule, the ratio to the length of the scale, of the distance of any number on the scale from the left-hand index, is equal to the mantissa of the logarithm of the number. It will be evident from a moment's study of the rule, that when the left-hand index is involved in multiplication, this corresponds to the addition of logarithms in which the sum of the mantissas is less than 1; and that when the left hand index is involved in division, this corresponds to the subtraction of logarithms in which the mantissa of the logarithm of the divisor is less than the mantissa of the logarithm of the dividend. It is important to visualize the lengths of the scale as mantissas of the corresponding numbers. Further study of the rule will show that when the right-hand index is involved in any operation, this indicates, in multiplication, the addition of logarithms in which the sum of the mantissas is greater than 1; or in division, the subtraction of logarithms in which the mantissa corresponding to the divisor is greater than that corresponding to the dividend. See (1) below.

The significance of these statements is that when the left-hand index is involved in an operation, the algebraic sum of the characteristics corresponding to the factors has not been affected—neither increased nor decreased; but when the right-hand index is involved, the algebraic sum of the characteristics corresponding to the factors has been affected, increased by 1 in multiplication or decreased by 1 in division. This statement may be extended as follows:

When the left-hand index only is involved in a series of operations, the characteristic of the logarithm of the result is equal to the algebraic sum of the characteristics of the logarithms of the factors, but whenever the right-hand index is involved in an operation, the characteristic of the logarithm of the result is equal to this algebraic sum plus or minus 1 for each operation in which this index is involved.

This correction (1 for each operation in which the right-hand index is involved) is always applied in the same way as the logarithm of the second factor would be, added in multiplication and subtracted in division. See (2) below.

In performing a series of operations, nothing is regarded except the correction to be applied to the algebraic sum of the characteristics of the logarithms of the factors. These corrections are added cumulatively at each operation, and only the accumulated sum is retained in the mind. We may call this accumulated sum the "accumulated characteristic correction." It is usually very small. We then have the following rule: The characteristic of the logarithm of the result is equal

to the algebraic sum of the characteristics corresponding to all the factors plus the accumulated characteristic correction. See (3) below.

To locate the decimal point, the characteristic for each factor is found as when working with common logarithms, and from the algebraic sum of these and the correction, the decimal point is located as when working with common logarithms.

The unavoidable prolixity of this explanation really disguises the simplicity of the method. The entire process is done mentally, quickly, and with ease.

The rule as stated above is true for all direct scales, but the method can be applied to all scales by visualizing the scale lengths as mantissas. This is really the important part of the process.

(1) It is customary to consider the use of the right-hand indices of scales as involving cologarithms. It may be found helpful in learning to locate the decimal point, to think only of the logarithms of the numbers, and to make all settings always using the left-hand index first. This will show that whenever the characteristic corresponding to a factor is involved, the result would lie on another scale identical with that being used, and lying immediately to the right or left of it. Crossing the index in this way, of course, indicates a change in the characteristic. This can be shown by squaring and cubing numbers on the fixed scales if it is not immediately obvious.

(2) The position of the slide always indicates whether the characteristic is being affected or not, but the necessity of noticing this can be eliminated by printing at the right-hand index the expression $\frac{+1}{-1}$. This will indicate that when that index is involved in multiplication the correction is +1 as is indicated by this being in the numerator, and for division the correction is −1 as is indicated by this being in the denominator.

(3) This rule is true only when these operations are performed in the usual way, where the result is always read on the fixed scale.

MONTHLY NORMALS OF SEA-LEVEL PRESSURE FOR THE UNITED STATES, CANADA, ALASKA, AND THE WEST INDIES.

By P. C. DAY, Meteorologist.

[Weather Bureau, Washington, D. C., Mar 3, 1924.]

The tables presented below show the averages of pressure reduced to sea level, at 8 a. m. and 8 p. m., 75th meridian time, respectively, for the regular Weather Bureau stations in the United States, and for the same hours at Canadian stations; also similar normals for points in Alaska, Hawaii, and the West Indies, at the special hours of observation.

The hours in Hawaii have been 8 a. m. and 8 p. m., standard time of the Territory, which is that of the meridian of 157° 30′ west, or 5½ hours behind 75th meridian time. The hours at stations in the West Indies have been in most instances 7 a. m. and 7 p. m., 75th meridian time, but these have varied in certain cases to secure better cable facilities. At the Alaskan stations a number of different hours have been used to promote better handling of reports; but the most usual hours have been 8 a. m. and 8 p. m., 135th meridian time, which is four hours behind 75th meridian time.

These values are based upon a period of 20 years' observations, 1901 to 1920, inclusive, and are published for the use of Weather Bureau forecasters and others interested in studies of barometric pressure.

The method of reduction from the observed station pressure, corrected for standard gravity and to a temperature of 32° F., to that of the sea level, is described by Prof. Frank H. Bigelow in the MONTHLY WEATHER REVIEW, January, 1902, 30:13–16.

At stations having records covering less than 20 years, approximate corrections have been made to reduce them to the full period. In cases where only one observation is made daily, data for the other hour have been interpolated by comparison with near-by stations.

In printing the data the first figure of the whole number of inches has been omitted and only the last figure and the decimal are shown, the whole inches being either 30 or 29.

The data for the Canadian stations were furnished through the courtesy of the director of that service, Sir Frederick Stupart; those for Cuba were extracted from the meteorological reports for that island.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
UNITED STATES.												
Abilene, Tex.:												
8 a. m.	0.14	0.11	0.03	9.96	9.90	9.92	9.96	9.96	0.00	0.06	0.13	0.14
8 p. m.	0.11	0.06	9.96	9.88	9.82	9.84	9.88	9.88	9.93	0.01	0.09	0.10
Albany, N. Y.:												
8 a. m.	0.10	0.08	0.07	0.00	0.00	0.00	9.98	0.03	0.10	0.11	0.07	0.08
8 p. m.	0.09	0.06	0.04	9.96	9.96	9.95	9.94	9.99	0.06	0.07	0.05	0.07
Albuquerque, N. Mex.:												
*8 a. m.	0.10	0.04	9.96	9.88	9.82	9.84	9.90	9.92	9.94	0.01	0.10	0.12
*8 p. m.	0.10	0.01	9.92	9.83	9.75	9.76	9.84	9.86	9.88	9.97	0.07	0.09
Alpena, Mich.:												
8 a. m.	0.05	0.07	0.05	0.01	0.01	0.00	9.99	0.02	0.07	0.06	0.02	0.03
8 p. m.	0.04	0.06	0.03	9.99	9.97	9.96	9.96	0.00	0.04	0.04	0.02	0.03
Amarillo, Tex.:												
8 a. m.	0.10	0.08	0.00	9.94	9.89	9.92	9.97	9.98	0.00	0.05	0.11	0.10
8 p. m.	0.08	0.04	9.95	9.88	9.81	9.84	9.89	9.90	9.94	0.01	0.08	0.08
Anniston, Ala.:												
8 a. m.	0.19	0.17	0.13	0.08	0.06	0.04	0.07	0.07	0.10	0.14	0.19	0.18
*8 p. m.	0.16	0.13	0.08	0.01	9.99	9.98	0.01	0.01	0.04	0.09	0.15	0.15
Apalachicola, Fla.:												
*8 a. m.	0.17	0.14	0.12	0.06	0.02	0.02	0.06	0.04	0.02	0.07	0.14	0.15
*8 p. m.	0.14	0.10	0.08	0.01	9.98	9.98	0.01	0.01	0.00	0.04	0.12	0.12
Asheville, N. C.:												
8 a. m.	0.16	0.15	0.12	0.05	0.05	0.04	0.06	0.07	0.12	0.15	0.19	0.17
8 p. m.	0.15	0.13	0.09	0.00	0.00	9.99	0.01	0.02	0.08	0.12	0.16	0.15
Atlanta, Ga.:												
8 a. m.	0.16	0.14	0.11	0.06	0.04	0.04	0.06	0.06	0.09	0.13	0.17	0.15
8 p. m.	0.15	0.12	0.08	0.01	9.99	9.98	0.01	0.02	0.05	0.10	0.14	0.14
Atlantic City, N. J.:												
8 a. m.	0.12	0.10	0.09	0.02	0.03	0.02	0.01	0.03	0.10	0.12	0.11	0.11
8 p. m.	0.11	0.07	0.06	9.98	0.00	9.98	9.98	0.01	0.08	0.09	0.08	0.10
Augusta, Ga.:												
8 a. m.	0.18	0.14	0.12	0.06	0.04	0.03	0.05	0.04	0.08	0.12	0.17	0.16
8 p. m.	0.14	0.10	0.06	9.99	9.97	9.97	9.99	9.99	0.03	0.07	0.12	0.14
Baker, Oreg.:												
8 a. m.	0.15	0.12	0.04	0.04	9.99	0.01	0.01	0.01	0.04	0.12	0.16	0.19
8 p. m.	0.15	0.10	0.01	9.98	9.93	9.94	9.93	9.94	9.98	0.09	0.14	0.18
Baltimore, Md.:												
8 a. m.	0.14	0.12	0.10	0.02	0.03	0.02	0.01	0.04	0.11	0.13	0.12	0.13
8 p. m.	0.12	0.09	0.06	9.97	9.98	9.97	9.96	0.00	0.07	0.09	0.09	0.11
Bentonville, Ark.:												
*8 a. m.	0.13	0.12	0.06	0.00	9.97	9.98	0.01	0.01	0.06	0.10	0.13	0.14
*8 p. m.	0.12	0.10	0.01	9.94	9.90	9.90	9.94	9.94	9.98	0.05	0.10	0.11
Billings, Mont.:												
*8 a. m.	0.13	0.16	0.07	0.01	9.94	9.94	9.99	9.99	0.03	0.10	0.14	0.14
*8 p. m.	0.12	0.12	0.03	9.95	9.90	9.88	9.91	9.91	9.97	0.07	0.13	0.14
Binghamton, N. Y.:												
8 a. m.	0.08	0.07	0.06	0.00	0.01	0.01	0.00	0.04	0.12	0.12	0.08	0.07
*8 p. m.	0.08	0.07	0.04	9.97	9.97	9.96	9.96	0.00	0.07	0.08	0.06	0.07
Birmingham, Ala.:												
8 a. m.	0.19	0.17	0.13	0.07	0.05	0.04	0.07	0.07	0.09	0.13	0.19	0.18
8 p. m.	0.16	0.13	0.08	0.01	9.99	9.98	0.01	0.01	0.03	0.09	0.16	0.16

* Values interpolated.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Con.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
UNITED STATES—con.												
Bismarck, N. Dak.:												
8 a. m.	0.16	0.21	0.09	0.04	9.98	9.95	9.98	0.00	0.02	0.06	0.10	0.14
8 p. m.	0.16	0.20	0.07	9.99	9.92	9.90	9.93	9.94	9.98	0.04	0.10	0.13
Block Island, R. I.:												
8 a. m.	0.07	0.03	0.04	9.98	0.00	0.00	9.99	0.03	0.10	0.10	0.05	0.05
8 p. m.	0.05	0.00	0.01	9.96	9.98	9.97	9.97	0.02	0.07	0.07	0.02	0.03
Boise, Idaho:												
8 a. m.	0.19	0.14	0.06	0.02	9.96	9.96	9.94	9.96	0.01	0.15	0.18	0.23
8 p. m.	0.18	0.12	0.02	9.96	9.89	9.88	9.85	9.87	9.94	0.08	0.16	0.22
Boston, Mass.:												
8 a. m.	0.06	0.02	0.03	9.98	0.00	0.00	9.97	0.03	0.10	0.09	0.04	0.04
8 p. m.	0.04	0.00	0.00	9.96	9.97	9.96	9.95	0.01	0.07	0.07	0.01	0.03
Broken Arrow, Okla:												
*8 a. m.	0.14	0.13	0.05	9.98	9.93	9.95	9.97	9.98	0.03	0.07	0.12	0.14
*8 p. m.	0.13	0.10	0.00	9.92	9.88	9.88	9.91	9.90	9.96	0.03	0.09	0.11
Brownsville, Tex.:												
8 a. m.	0.10	0.06	0.00	9.93	9.90	9.92	9.96	9.94	9.94	9.99	0.08	0.08
8 p. m.	0.07	0.03	9.96	9.89	9.85	9.87	9.92	9.89	9.90	9.96	0.05	0.06
Buffalo, N. Y.:												
8 a. m.	0.05	0.06	0.04	0.00	0.00	0.00	9.99	0.02	0.08	0.08	0.05	0.04
8 p. m.	0.05	0.05	0.04	9.98	9.97	9.96	9.95	9.99	0.06	0.06	0.04	0.05
Burlington, Vt.:												
8. a. m	0.07	0.05	0.03	0.00	9.98	9.99	9.96	0.02	0.08	0.08	0.05	0.09
*8 p. m.	0.06	0.02	0.02	9.96	9.95	9.95	9.94	0.01	0.07	0.07	0.02	0.03
Burrwood, La.:												
*8 a. m.	0.17	0.13	0.10	0.05	0.01	0.01	0.04	0.03	0.01	0.07	0.14	0.15
*8 p. m.	0.13	0.09	0.06	9.99	9.96	9.96	0.00	9.98	9.97	0.02	0.10	0.11
Cairo, Ill.:												
8 a. m.	0.16	0.16	0.09	0.03	0.00	0.00	0.02	0.02	0.08	0.12	0.16	0.16
8 p. m.	0.14	0.12	0.04	9.98	9.94	9.94	9.96	9.96	0.02	0.07	0.12	0.13
Canton, N. Y.:												
8 a. m.	0.07	0.05	0.02	9.99	9.97	9.99	9.96	0.01	0.07	0.07	0.04	0.05
*8 p. m.	0.05	0.03	0.02	9.97	9.94	9.95	9.93	9.97	0.05	0.05	0.02	0.04
Cape Henry, Va.:												
*8 a. m.	0.14	0.12	0.10	0.03	0.03	0.02	0.04	0.04	0.10	0.12	0.13	0.13
8 p. m.	0.12	0.08	0.06	0.00	9.99	9.99	9.99	0.01	0.07	0.09	0.10	0.11
Cape May, N. J.:												
8 a. m.	0.15	0.12	0.11	0.04	0.05	0.04	0.04	0.06	0.12	0.14	0.13	0.13
8 p. m.	0.12	0.09	0.07	0.00	0.01	0.00	0.00	0.03	0.10	0.11	0.10	0.12
Charles City, Iowa:												
8 a. m.	0.12	0.14	0.06	0.00	9.97	9.98	9.99	0.01	0.06	0.06	0.08	0.10
8 p. m.	0.12	0.13	0.04	9.96	9.92	9.93	9.94	9.96	0.01	0.04	0.07	0.09
Charleston, S. C.:												
8 a. m.	0.17	0.14	0.12	0.06	0.04	0.03	0.06	0.05	0.07	0.10	0.15	0.13
8 p. m.	0.14	0.10	0.08	0.02	0.00	9.99	0.02	0.02	0.04	0.07	0.12	0.13
Charlotte, N. C.:												
8 a. m.	0.16	0.14	0.12	0.06	0.04	0.04	0.05	0.06	0.11	0.14	0.17	0.15
8 p. m.	0.14	0.10	0.07	9.99	9.98	9.98	0.00	0.01	0.07	0.10	0.13	0.13
Chattanooga, Tenn.:												
8 a. m.	0.19	0.18	0.14	0.08	0.06	0.04	0.07	0.07	0.12	0.18	0.21	0.19
8 p. m.	0.16	0.14	0.08	0.01	9.98	9.98	0.00	0.01	0.05	0.11	0.16	0.16
Cheyenne, Wyo.:												
8 a. m.	0.06	0.08	0.00	9.96	9.89	9.90	9.96	9.98	0.00	0.06	0.10	0.09
8 p. m.	0.07	0.07	9.99	9.93	9.85	9.85	9.92	9.93	9.96	0.04	0.10	0.10
Chicago, Ill.:												
8 a. m.	0.10	0.12	0.06	0.01	0.00	0.00	0.01	0.02	0.08	0.08	0.09	0.09
8 p. m.	0.09	0.11	0.04	9.99	9.96	9.96	9.97	9.99	0,04	0.06	0.08	0.09
Cincinnati, Ohio:												
8 a. m.	0.15	0.15	0.10	0.04	0.02	0.02	0.03	0.04	0.11	0.14	0.16	0.14
8 p. m.	0.13	0.12	0.06	9.99	9.97	9.96	9.97	9.98	0.05	0.10	0.13	0.13
Cleveland, Ohio:												
8 a. m.	0.09	0.10	0.06	0.01	0.01	0.01	0.01	0.03	0.10	0.10	0.09	0.08
8 p. m.	0.09	0.09	0.05	9.98	9.97	9.97	9.97	9.99	0.06	0.08	0.07	0.08
Columbia, Mo.:												
*8 a. m.	0.14	0.14	0.06	9.99	9.97	9.97	9.99	0.00	0.06	0.08	0.12	0.13
8 p. m.	0.13	0.12	0.01	9.95	9.90	9.91	9.93	9.94	9.99	0.05	0.10	0.11
Columbia, S. C.:												
8 a. m	0.18	0.15	0.13	0.06	0.05	0.03	0.05	0.05	0.10	0.13	0.17	0.16
8 p. m.	0.15	0.11	0.08	0.00	9.99	9.98	0.00	0.00	0.05	0.09	0.13	0.14
Columbus, Ohio:												
8 a. m.	0.12	0.12	0.08	0.02	0.02	0.02	0.03	0.04	0.11	0.13	0.13	0.12
8 p. m.	0.11	0.11	0.05	9.99	9.97	9.97	9.98	9.99	0.06	0.09	0.11	0.11
Concord, N. H.:												
8 a. m.	0.07	0.05	0.04	9.98	9.99	0.00	9.97	0.03	0.10	0.10	0.04	0.04
*8 p. m.	0.05	0.01	0.00	9.96	9.97	9.96	9.95	0.01	0.07	0.07	0.01	0.03
Concordia, Kans.:												
8 a. m.	0.15	0.16	0.05	0.00	9.93	9.94	9.97	9.99	0.03	0.07	0.13	0.14
8 p. m.	0.14	0.13	0.02	9.94	9.87	9.88	9.90	9.92	9.97	0.04	0.11	0.13
Corinth, Miss.:												
*8 a. m.	0.19	0.18	0.12	0.07	0.04	0.03	0.06	0.06	0.10	0.14	0.19	0.18
*8 p. m.	0.16	0.14	0.07	0.01	9.98	9.98	0.00	0.00	0.03	0.10	0.16	0.15
Corpus Christi, Tex.:												
8 a. m.	0.14	0.11	0.04	9.98	9.93	9.95	0.00	9.98	9.98	0.04	0.12	0.13
8 p. m.	0.11	0.07	9.99	9.92	9.88	9.90	9.94	9.93	9.93	0.00	0.08	0.10
Dallas, Tex.:												
*8 a. m.	0.14	0.13	0.05	9.98	9.94	9.95	9.99	9.99	0.02	0.08	0.13	0.13
*8 p. m.	0.12	0.09	9.99	9.90	9.86	9.89	9.90	9.89	9.95	0.02	0.09	0.10
Davenport, Iowa:												
8 a. m.	0.13	0.14	0.06	0.00	9.97	9.98	0.00	0.02	0.07	0.08	0.10	0.12
8 p. m.	0.12	0.13	0.03	9.95	9.92	9.93	9.94	9.96	0.01	0.04	0.08	0.10
Dayton, Ohio:												
*8 a. m.	0.13	0.13	0.09	0.03	0.02	0.02	0.03	0.04	0.11	0.13	0.14	0.13
* 8 p. m.	0.12	0.11	0.05	9.99	9.96	9.96	9.97	9.99	0.05	0.09	0.12	0.11
Del Rio, Tex.:												
8 a. m.	0.12	0.09	0.02	9.93	9.88	9.89	9.93	9.92	9.95	0.02	0.10	0.12
*8 p. m.	0.10	0.05	9.95	9.86	9.80	9.83	9.87	9.85	9.90	9.95	0.05	0.07
Denver, Colo.:												
8 a. m.	0.07	0.07	9.99	9.96	9.90	9.92	9.97	9.99	0.01	0.06	0.11	0.10
8 p. m.	0.06	0.04	9.95	9.90	9.82	9.84	9.92	9.93	9.94	0.02	0.08	0.09

* Values interpolated.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Con.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	cember.
UNITED STATES—con.												
Des Moines, Iowa:												
8 a. m.	0.12	0.14	0.05	0.00	9.95	9.96	9.98	0.00	0.04	0.06	0.09	0.11
8 p. m.	0.12	0.13	0.02	9.94	9.90	9.90	9.92	9.94	9.99	0.03	0.08	0.10
Detroit, Mich.:												
8 a. m.	0.08	0.09	0.06	0.01	0.01	0.01	0.00	0.03	0.09	0.09	0.08	0.07
8 p. m.	0.08	0.08	0.04	9.99	9.97	9.97	9.96	9.99	0.06	0.07	0.07	0.06
Devils Lake, N. Dak.:												
8 a. m.	0.11	0.16	0.06	0.01	9.96	9.92	9.95	9.96	9.99	0.03	0.07	0.10
8 p. m.	0.11	0.15	0.05	9.97	9.91	9.88	9.91	9.92	9.95	9.99	0.03	0.07
Dodge City, Kans.:												
8 a. m.	0.15	0.13	0.05	0.02	9.92	9.93	9.96	9.93	0.02	0.08	0.14	0.15
8 p. m.	0.12	0.10	0.00	9.90	9.83	9.85	9.88	9.89	9.94	0.03	0.10	0.12
Drexel, Nebr.:												
*8 a. m.	0.14	0.15	0.05	0.00	9.94	9.95	9.97	9.99	0.03	0.06	0.10	0.12
*8 p. m.	0.14	0.14	0.02	9.94	9.88	9.89	9.91	9.93	9.97	0.03	0.09	0.12
Dubuque, Iowa.:												
8 a. m.	0.14	0.16	0.07	0.02	9.99	0.00	0.01	0.03	0.08	0.09	0.10	0.12
8 p. m.	0.13	0.14	0.04	9.97	9.94	9.94	9.95	9.97	0.02	0.05	0.09	0.11
Due West, S. C.:												
8 a. m.	0.16	0.15	0.12	0.06	0.05	0.04	0.06	0.06	0.11	0.14	0.18	0.16
8 p. m.	0.15	0.12	0.08	0.00	9.99	9.98	0.01	0.01	0.07	0.11	0.15	0.15
Duluth, Minn.:												
8 a. m.	0.08	0.12	0.05	0.03	0.00	9.98	9.97	0.00	0.03	0.02	0.03	0.06
8 p. m.	0.08	0.10	0.03	9.99	9.96	9.94	9.94	9.96	0.00	0.01	0.03	0.05
Durango, Colo.:												
*8. a. m.	0.13	0.06	9.98	9.90	9.84	9.86	9.93	9.95	9.97	0.04	0.10	0.15
*8 p. m.	0.10	0.03	9.92	9.83	9.75	9.77	9.84	9.86	9.89	9.98	0.09	0.13
Eastport, Me.:												
8 a. m.	0.00	9.94	9.97	9.95	9.96	9.96	9.94	0.00	0.06	0.05	9.97	9.97
8 p. m.	9.99	9.92	9.96	9.94	9.94	9.94	9.92	9.98	0.04	0.03	9.96	9.96
Elkins, W. Va.:												
8 a. m.	0.14	0.14	0.10	0.04	0.04	0.03	0.05	0.06	0.15	0.17	0.17	0.15
8 p. m.	0.13	0.12	0.08	0.00	9.99	9.99	0.00	0.02	0.10	0.14	0.15	0.14
Ellendale, N. Dak.:												
*8 a. m.	0.15	0.20	0.08	0.04	9.98	9.95	9.98	0.00	0.02	0.05	0.10	0.13
*8 p. m.	0.14	0.19	0.06	9.98	9.92	9.90	9.92	9.94	9.98	0.03	0.09	0.12
El Paso, Tex.:												
8 a. m.	0.08	0.02	9.96	9.88	9.81	9.81	9.87	9.89	9.91	9.98	0.07	0.08
8 p. m.	0.03	9.96	9.87	9.78	9.70	9.70	9.77	9.80	9.83	9.90	0.01	0.04
Erie, Pa.:												
8 a. m.	0.07	0.08	0.05	0.00	0.00	0.00	9.99	0.02	0.09	0.09	0.07	0.06
8 p. m.	0.07	0.07	0.04	9.98	9.97	9.96	9.96	9.99	0.06	0.06	0.05	0.06
Escanaba, Mich.:												
8 a. m.	0.05	0.09	0.05	0.02	0.00	9.99	9.98	0.01	0.05	0.04	0.03	0.04
8 p. m.	0.05	0.08	0.04	0.00	9.96	9.95	9.94	9.98	0.02	0.02	0.02	0.04
Eureka, Calif.:												
8 a. m.	0.09	0.07	0.07	0.09	0.06	0.05	0.03	0.01	0.01	0.07	0.11	0.13
8 p. m.	0.08	0.06	0.07	0.10	0.08	0.07	0.05	0.03	0.02	0.07	0.10	0.12
Evansville, Ind.:												
8 a. m.	0.15	0.15	0.09	0.03	0.01	0.00	0.02	0.03	0.09	0.12	0.16	0.15
8 p. m.	0.13	0.12	0.06	9.99	9.96	9.95	9.97	9.98	0.04	0.07	0.13	0.13
Flagstaff, Ariz.:												
8 a. m.	0.07	9.99	9.93	9.87	9.82	9.83	9.88	9.91	9.92	9.98	0.06	0.07
8 p. m.	0.06	9.98	9.92	9.84	9.78	9.79	9.84	9.87	9.88	9.95	0.04	0.07
Fort Myers, Fla.:												
*8 a. m.	0.14	0.13	0.11	0.06	0.01	0.01	0.05	0.03	9.99	0.01	0.10	0.13
*8 p. m.	0.13	0.10	0.07	0.02	9.98	9.98	0.03	0.02	9.97	9.99	0.08	0.11
Fort Smith, Ark.:												
8 a. m.	0.14	0.13	0.05	0.00	9.96	9.97	9.99	9.99	0.04	0.09	0.14	0.14
8 p. m.	0.12	0.09	9.99	9.92	9.88	9.89	9.92	9.92	9.96	0.03	0.09	0.11
Fort Wayne, Ind.:												
*8 a. m.	0.10	0.12	0.07	0.02	0.02	0.01	0.02	0.03	0.10	0.10	0.10	0.10
*8 p. m.	0.09	0.10	0.05	9.99	9.97	9.96	9.96	9.99	0.05	0.07	0.09	0.10
Fort Worth, Tex.:												
8 a. m.	0.14	0.12	0.04	9.98	9.93	9.94	9.98	9.98	0.01	0.07	0.13	0.13
*8 p. m.	0.12	0.08	9.98	9.90	9.85	9.88	9.90	9.89	9.94	0.02	0.09	0.10
Fresno, Calif.:												
8 a. m.	0.13	0.09	0.05	0.01	9.94	9.89	9.87	9.87	9.90	0.00	0.10	0.15
8 p. m.	0.11	0.06	0.02	9.96	9.88	9.82	9.80	9.80	9.84	9.95	0.07	0.13
Galveston, Tex.:												
8 a. m.	0.15	0.12	0.07	0.01	9.97	9.98	0.02	0.01	0.00	0.06	0.14	0.14
8 p. m.	0.13	0.09	0.03	9.97	9.93	9.94	9.98	9.96	9.96	0.03	0.11	0.11
Grand Forks, N. Dak.:												
*8 a. m.	0.12	0.16	0.06	0.01	9.97	9.93	9.96	9.95	0.00	0.03	0.07	0.10
*8 p. m.	0.12	0.16	0.05	9.97	9.91	9.89	9.92	9.92	9.96	9.99	0.04	0.08
Grand Haven, Mich.:												
8 a. m.	0.06	0.09	0.04	0.00	9.98	9.98	9.98	0.01	0.06	0.06	0.05	0.05
8 p. m.	0.06	0.08	0.03	9.97	9.95	9.94	9.94	9.97	0.03	0.04	0.04	0.05
Grand Junction, Colo.:												
8 a. m.	0.19	0.08	9.98	9.91	9.85	9.88	9.94	9.97	9.98	0.05	0.13	0.18
8 p. m.	0.16	0.03	9.91	9.82	9.75	9.77	9.83	9.86	9.89	9.98	0.08	0.15
Grand Rapids, Mich.:												
8 a. m.	0.08	0.10	0.06	0.01	0.00	0.01	0.01	0.03	0.09	0.08	0.06	0.09
8 p. m.	0.07	0.09	0.04	9.98	9.96	9.96	9.95	9.98	0.05	0.05	0.06	0.06
Green Bay, Wis.:												
8 a. m.	0.07	0.10	0.04	0.00	9.98	9.98	9.98	0.01	0.04	0.04	0.03	0.05
8 p. m.	0.06	0.08	0.01	9.96	9.93	9.93	9.93	9.96	0.01	0.01	0.02	0.05
Greenville, Me.:												
8 a. m.	0.01	9.97	9.96	9.98	9.97	9.98	9.96	0.03	0.08	0.06	0.00	9.99
8 p. m.	0.00	9.96	9.94	9.96	9.94	9.95	9.94	0.00	0.06	0.03	9.99	9.98
Greenville, S. C.:												
*8 a. m.	0.16	0.15	0.12	0.06	0.05	0.04	0.06	0.06	0.11	0.14	0.18	0.16
*8 p. m.	0.15	0.12	0.08	0.00	9.99	9.98	0.01	0.01	0.07	0.11	0.15	0.15
Groesbeck, Tex.:												
*8 a. m.	0.15	0.12	0.05	9.98	9.94	9.95	0.00	9.99	0.01	0.07	0.13	0.14
*8 p. m.	0.12	0.07	9.98	9.90	9.86	9.88	9.90	9.90	9.94	0.02	0.09	0.10

* Values interpolated.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Con.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
UNITED STATES—con.												
Hannibal, Mo.:												
8 a. m.	0.14	0.14	0.06	0.00	9.97	9.98	0.00	0.01	0.07	0.09	0.12	0.13
*8 p. m.	0.14	0.13	0.02	9.96	9.91	9.92	9.94	9.96	0.01	0.06	0.11	0.11
Harrisburg, Pa.:												
8 a. m.	0.13	0.12	0.10	0.03	0.03	0.02	0.02	0.05	0.12	0.14	0.12	0.12
8 p. m.	0.12	0.11	0.07	9.98	9.98	9.97	9.96	0.01	0.08	0.10	0.10	0.11
Hartford, Conn.:												
8 a. m.	0.09	0.06	0.05	9.99	0.00	0.00	9.99	0.03	0.10	0.10	0.05	0.06
8 p. m.	0.07	0.03	0.02	9.97	9.97	9.96	9.95	0.00	0.07	0.07	0.03	0.05
Hatteras, N. C.:												
8 a. m.	0.14	0.11	0.10	0.03	0.03	0.02	0.04	0.04	0.08	0.10	0.12	0.12
8 p. m.	0.12	0.08	0.07	0.00	0.00	0.00	0.01	0.02	0.06	0.08	0.10	0.11
Havre, Mont.:												
8 a. m.	0.10	0.15	0.04	9.99	9.93	9.91	9.95	9.96	9.99	0.06	0.05	0.07
8 p. m.	0.10	0.13	0.01	9.93	9.87	9.85	9.88	9.90	9.94	0.00	0.09	0.07
Helena, Mont.:												
8 a. m.	0.11	0.13	0.04	0.00	9.94	9.94	9.98	9.99	0.02	0.08	0.12	0.13
8 p. m.	0.10	0.10	0.00	9.94	9.89	9.88	9.90	9.91	9.96	0.05	0.10	0.12
Houghton, Mich.:												
8 a. m.	0.03	0.08	0.04	0.02	9.99	9.97	9.96	9.99	0.02	0.01	0.00	0.02
*8 p. m.	0.03	0.08	0.03	9.99	9.96	9.95	9.93	9.97	0.00	0.00	0.00	0.02
Houston, Tex.:												
*8 a. m.	0.15	0.12	0.07	0.00	9.97	9.98	0.01	0.00	0.00	0.06	0.14	0.14
*8 p. m.	0.13	0.08	0.02	9.96	9.92	9.92	9.96	9.95	9.96	0.03	0.11	0.11
Huron, S. Dak.:												
8 a. m.	0.16	0.20	0.08	0.03	9.97	9.95	9.98	0.00	0.03	0.06	0.11	0.14
8 p. m.	0.15	0.18	0.05	9.97	9.91	9.90	9.92	9.94	9.98	0.03	0.10	0.13
Independence, Calif.:												
8 a. m.	0.10	0.03	9.97	9.92	9.85	9.84	9.87	9.86	9.90	0.00	0.09	0.13
8 p. m.	0.06	9.99	9.92	9.85	9.77	9.76	9.79	9.80	9.83	9.94	0.04	0.08
Indianapolis. Ind.:												
8 a. m.	0.13	0.13	0.08	0.02	0.02	0.01	0.03	0.04	0.10	0.12	0.13	0.12
8 p. m.	0.11	0.11	0.05	9.99	9.96	9.96	9.97	9.99	0.05	0.08	0.11	0.11
Iola, Kans.:												
8 a. m.	0.14	0.13	0.05	9.99	9.94	9.96	9.98	9.99	0.04	0.07	0.13	0.14
*8 p. m.	0.13	0.11	0.01	9.93	9.88	9.89	9.93	9.93	9.97	0.04	0.10	0.11
Jacksonville, Fla.:												
8 a. m.	0.17	0.14	0.12	0.06	0.03	0.03	0.06	0.05	0.04	0.06	0.14	0.15
8 p. m.	0.15	0.11	0.08	0.02	9.99	9.99	0.03	0.02	0.01	0.04	0.11	0.13
Kalispell, Mont.:												
8 a. m.	0.10	0.11	0.01	9.99	9.94	9.94	9.96	9.97	0.00	0.07	0.10	0.12
8 p. m.	0.09	0.08	9.97	9.93	9.88	9.88	9.88	9.90	9.95	0.04	0.08	0.12
Kansas City, Mo.:												
8 a. m.	0.14	0.14	0.05	9.99	9.95	9.96	9.98	9.99	0.05	0.08	0.12	0.13
8 p. m.	0.13	0.12	0.01	9.94	9.89	9.89	9.92	9.93	9.98	0.04	0.10	0.11
Keokuk, Iowa:												
8 a. m.	0.14	0.15	0.07	0.01	9.98	9.99	0.01	0.02	0.07	0.09	0.13	0.13
8 p. m.	0.14	0.14	0.04	9.97	9.92	9.93	9.95	9.97	0.02	0.06	0.12	0.12
Key West, Fla.:												
8 a. m.	0.11	0.10	0.08	0.03	9.98	9.99	0.04	0.02	9.96	9.96	0.05	0.09
8 p. m.	0.10	0.08	0.05	0.00	9.96	9.98	0.03	0.00	9.94	9.94	0.03	0.08
Knoxville, Tenn.:												
8 a. m.	0.17	0.15	0.11	0.05	0.04	0.03	0.05	0.05	0.11	0.15	0.18	0.16
8 p. m.	0.14	0.11	0.06	9.99	9.97	9.97	9.99	9.99	0.04	0.10	0.14	0.14
La Crosse, Wis.:												
8 a. m.	0.11	0.13	0.04	0.00	9.97	9.97	9.98	0.00	0.05	0.05	0.07	0.09
8 p. m.	0.11	0.12	0.03	9.96	9.92	9.93	9.94	9.96	0.02	0.03	0.07	0.08
Lake Charles, La.:												
*8 a. m.	0.15	0.13	0.08	0.03	9.99	9.99	0.02	0.01	0.01	0.07	0.15	0.15
*8 p. m.	0.14	0.10	0.03	9.97	9.94	9.94	9.98	9.96	9.97	0.04	0.11	0.12
Lander, Wyo.:												
8 a. m.	0.16	0.14	0.03	9.99	9.92	9.93	9.98	0.00	0.03	0.11	0.17	0.21
8 p. m.	0.14	0.11	9.99	9.93	9.85	9.84	9.88	9.90	9.95	0.07	0.16	0.20
Lansing, Mich.:												
*8 a. m.	0.08	0.09	0.06	0.01	0.01	0.01	0.00	0.03	0.09	0.08	0.06	0.08
*8 p. m.	0.07	0.08	0.04	9.99	9.97	9.96	9.95	9.98	0.05	0.06	0.06	0.07
Lewiston, Idaho:												
8 a. m.	0.12	0.11	0.03	0.03	9.97	9.97	9.95	9.96	0.00	0.09	0.12	0.15
8 p. m.	0.10	0.08	0.00	9.97	9.92	9.90	9.90	9.91	9.96	0.06	0.10	0.14
Lexington, Ky.:												
8 a. m.	0.16	0.15	0.10	0.04	0.03	0.02	0.04	0.05	0.11	0.14	0.17	0.16
*8 p. m.	0.14	0.13	0.07	0.00	9.98	9.98	9.98	0.00	0.06	0.10	0.14	0.14
Lincoln, Nebr.:												
8 a. m.	0.14	0.15	0.04	9.98	9.92	9.93	9.96	9.97	0.02	0.05	0.11	0.12
8 p. m.	0.13	0.13	0.01	9.93	9.86	9.87	9.89	9.91	9.96	0.02	0.08	0.11
Little Rock, Ark.:												
8 a. m.	0.16	0.15	0.08	0.02	9.98	9.99	0.02	0.01	0.06	0.11	0.16	0.16
8 p. m.	0.14	0.11	0.02	9.96	9.92	9.93	9.95	9.95	9.99	0.06	0.12	0.13
Los Angeles, Calif.:												
8 a. m.	0.07	0.05	0.02	9.98	9.94	9.91	9.92	9.92	9.91	9.97	0.04	0.07
8 p. m.	0.06	0.03	0.00	9.96	9.92	9.88	9.88	9.88	9.87	9.93	0.01	0.04
Louisville, Ky.:												
8 a. m.	0.16	0.16	0.11	0.05	0.04	0.03	0.05	0.06	0.12	0.14	0.17	0.16
8 p. m.	0.15	0.14	0.07	0.00	9.98	9.98	9.99	0.00	0.06	0.10	0.14	0.14
Ludington, Mich.:												
8 a. m.	0.06	0.08	0.04	0.01	0.01	0.00	0.00	0.01	0.07	0.05	0.04	0.05
*8 p. m.	0.05	0.07	0.03	9.99	9.96	9.95	9.95	9.98	0.03	0.03	0.03	0.05
Lynchburg, Va.:												
8 a. m.	0.14	0.12	0.10	0.04	0.04	0.03	0.04	0.05	0.12	0.15	0.15	0.14
8 p. m.	0.12	0.08	0.05	9.97	9.97	9.97	9.98	0.00	0.08	0.10	0.11	0.12
Macon, Ga.:												
8 a. m.	0.17	0.15	0.12	0.06	0.03	0.03	0.05	0.04	0.07	0.12	0.17	0.16
*8 p. m.	0.15	0.12	0.08	0.01	9.98	9.98	0.01	0.01	0.02	0.07	0.13	0.14
Madison, Wis.:												
8 a. m.	0.10	0.12	0.05	0.00	9.98	9.99	0.00	0.02	0.06	0.06	0.07	0.08
8 p. m.	0.10	0.11	0.04	9.97	9.94	9.95	9.95	9.97	0.03	0.04	0.07	0.08
Marquette, Mich.:												
8 a. m.	0.05	0.10	0.06	0.04	0.02	0.00	9.99	0.02	0.05	0.04	0.02	0.03
8 p. m.	0.04	0.09	0.06	0.02	9.99	9.98	9.96	0.00	0.03	0.03	0.02	0.03

* Values interpolated.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Contd.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
UNITED STATES—con.												
Marshfield, Oreg.:												
*8 a. m.	0.07	0.05	0.05	0.09	0.06	0.07	0.04	0.04	0.02	0.06	0.08	0.10
*8 p. m.	0.06	0.04	0.04	0.08	0.07	0.08	0.06	0.05	0.02	0.06	0.07	0.10
Medford, Oreg.:												
*8 a. m.	0.09	0.06	0.05	0.08	0.04	0.05	0.02	0.02	0.00	0.07	0.10	0.14
*8 p. m.	0.07	0.04	0.01	0.02	9.99	9.95	9.93	9.90	9.95	0.02	0.07	0.12
Memphis, Tenn.:												
8 a. m.	0.19	0.18	0.12	0.06	0.03	0.03	0.05	0.04	0.09	0.14	0.19	0.18
8 p. m.	0.16	0.14	0.06	0.00	9.97	9.97	9.99	9.99	0.03	0.10	0.15	0.15
Meridian, Miss.:												
8 a. m.	0.17	0.15	0.10	0.05	0.01	0.01	0.03	0.02	0.04	0.10	0.17	0.16
*8 p. m.	0.15	0.12	0.07	9.99	9.97	9.96	9.99	9.99	0.00	0.07	0.14	0.15
Miami, Fla.:												
*8 a. m.	0.14	0.12	0.10	0.05	0.02	0.02	0.05	0.03	9.98	9.99	0.08	0.12
*8 p. m.	0.13	0.10	0.08	0.03	9.99	0.00	0.05	0.03	9.98	9.98	0.06	0.11
Miles City, Mont.:												
8 a. m.	0.14	0.19	0.10	0.02	9.94	9.94	9.96	9.96	0.02	0.08	0.12	0.14
8 p. m.	0.11	0.17	0.05	9.96	9.90	9.86	9.89	9.90	9.97	0.05	0.10	0.13
Milwaukee, Wis.:												
8 a. m.	0.08	0.11	0.05	0.01	0.00	0.00	0.00	0.03	0.07	0.07	0.06	0.07
8 p. m.	0.08	0.10	0.03	9.98	9.96	9.96	9.97	9.99	0.04	0.05	0.06	0.07
Minneapolis, Minn.:												
8 a. m.	0.10	0.14	0.04	0.00	9.96	9.95	9.97	0.00	0.02	0.03	0.06	0.08
*8 p. m.	0.09	0.12	0.02	9.95	9.91	9.91	9.93	9.95	9.98	0.00	0.04	0.06
Mobile, Ala.:												
8 a. m.	0.17	0.14	0.10	0.05	0.01	0.01	0.04	0.03	0.02	0.08	0.15	0.15
8 p. m.	0.14	0.10	0.06	0.00	9.96	9.96	0.00	9.98	9.98	0.04	0.12	0.13
Modena, Utah:												
8 a. m.	0.12	0.05	9.97	9.90	9.84	9.85	9.90	9.92	9.94	0.03	0.12	0.15
8 p. m.	0.10	0.02	9.93	9.85	9.78	9.78	9.82	9.85	9.88	9.98	0.08	0.13
Montgomery, Ala.:												
8 a. m.	0.19	0.17	0.13	0.07	0.04	0.03	0.06	0.05	0.06	0.12	0.19	0.18
8 p. m.	0.16	0.12	0.07	0.00	9.97	9.96	0.00	9.99	0.01	0.07	0.14	0.15
Moorhead, Minn.:												
8 a. m.	0.15	0.19	0.08	0.04	9.98	9.95	9.97	0.00	0.02	0.04	0.08	0.12
8 p. m.	0.13	0.18	0.06	9.99	9.92	9.91	9.92	9.94	9.98	0.02	0.07	0.11
Muskogee, Okla.:												
*8 a. m.	0.14	0.13	0.05	9.99	9.94	9.96	9.98	9.99	0.04	0.08	0.13	0.14
*8 p. m.	0.13	0.10	0.00	9.92	9.89	9.88	9.92	9.91	9.97	0.04	0.09	0.11
Nantucket, Mass.:												
8 a. m.	0.05	0.00	0.02	9.97	9.99	0.00	9.98	0.02	0.08	0.08	0.02	0.02
8 p. m.	0.03	9.98	0.00	9.95	9.98	9.97	9.97	0.02	0.07	0.06	0.00	0.01
Nashville, Tenn.:												
8 a. m.	0.18	0.17	0.12	0.06	0.04	0.03	0.05	0.06	0.11	0.15	0.19	0.18
8 p. m.	0.16	0.14	0.07	0.01	9.98	9.97	9.99	0.00	0.05	0.11	0.16	0.15
Needles, Calif.:												
*8 a. m.	0.06	0.02	9.96	9.90	9.82	9.80	9.84	9.84	9.85	9.94	0.04	0.06
*8 p. m.	0.05	9.98	9.91	9.82	9.75	9.74	9.76	9.77	9.83	9.90	0.00	0.05
New Haven, Conn.:												
8 a. m.	0.09	0.06	0.06	9.99	0.01	0.00	9.99	0.03	0.10	0.10	0.06	0.07
8 p. m.	0.07	0.03	0.03	9.97	9.97	9.96	9.96	0.01	0.07	0.08	0.03	0.06
New Orleans, La.:												
8 a. m.	0.16	0.13	0.09	0.04	0.00	0.00	0.03	0.02	0.00	0.06	0.15	0.15
8 p. m.	0.14	0.10	0.05	9.98	9.95	9.95	9.99	9.97	9.96	0.03	0.11	0.12
New York, N. Y.:												
8 a. m.	0.10	0.07	0.07	0.00	0.01	0.00	0.00	0.03	0.10	0.10	0.08	0.08
8 p. m.	0.08	0.05	0.03	9.96	9.97	9.96	9.96	0.00	0.07	0.08	0.05	0.07
Norfolk, Va.:												
8 a. m.	0.15	0.13	0.11	0.04	0.04	0.03	0.04	0.04	0.11	0.13	0.14	0.14
8 p. m.	0.13	0.09	0.07	0.00	0.00	9.99	0.00	0.01	0.08	0.10	0.11	0.12
Northfield, Vt.:												
8 a. m.	0.07	0.04	0.04	9.99	0.00	0.00	9.98	0.04	0.11	0.10	0.05	0.06
8 p. m.	0.06	0.02	0.02	9.97	9.96	9.96	9.95	0.02	0.08	0.08	0.03	0.04
North Head, Wash.:												
8 a. m.	0.00	0.02	0.01	0.08	0.06	0.07	0.07	0.06	0.03	0.06	0.02	0.03
8 p. m.	0.00	0.01	0.01	0.08	0.07	0.09	0.08	0.07	0.03	0.06	0.02	0.03
North Platte, Nebr.:												
8 a. m.	0.16	0.17	0.06	0.01	9.94	9.96	9.99	0.01	0.04	0.09	0.15	0.16
8 p. m.	0.15	0.15	0.03	9.95	9.88	9.89	9.92	9.94	9.98	0.05	0.13	0.15
OklahomaCity, Okla.:												
8 a. m.	0.14	0.12	0.04	9.97	9.92	9.94	9.97	9.98	0.02	0.07	0.12	0.13
8 p. m.	0.12	0.09	9.98	9.91	9.85	9.87	9.90	9.90	9.95	0.03	0.10	0.11
Omaha, Nebr.:												
8 a. m.	0.14	0.15	0.05	0.00	9.94	9.95	9.97	9.99	0.03	0.06	0.10	0.12
8 p. m.	0.14	0.14	0.02	9.94	9.88	9.89	9.91	9.93	9.97	0.03	0.09	0.12
Oswego, N. Y.:												
8 a. m.	0.06	0.06	0.04	9.99	0.00	9.99	9.98	0.02	0.08	0.08	0.04	0.05
8 p. m.	0.06	0.04	0.03	9.97	9.95	9.95	9.93	9.98	0.05	0.05	0.03	0.05
Palestine, Tex.:												
8 a. m.	0.15	0.13	0.06	0.01	9.96	9.97	0.01	0.00	0.02	0.08	0.14	0.14
8 p. m.	0.12	0.08	0.00	9.94	9.89	9.90	9.93	9.92	9.95	0.03	0.10	0.11
Parkersburg, W. Va.:												
8 a. m.	0.14	0.14	0.10	0.04	0.04	0.04	0.04	0.06	0.12	0.15	0.16	0.15
8 p. m.	0.13	0.12	0.07	0.00	9.98	9.98	9.99	0.01	0.07	0.11	0.13	0.13
Pensacola, Fla.:												
8 a. m.	0.17	0.14	0.11	0.05	0.02	0.01	0.05	0.03	0.02	0.08	0.15	0.15
8 p. m.	0.15	0.11	0.07	0.01	9.97	9.97	0.01	9.99	9.98	0.04	0.12	0.13
Peoria, Ill.:												
8 a. m.	0.12	0.13	0.06	0.01	9.99	0.00	0.01	0.02	0.08	0.08	0.10	0.11
8 p. m.	0.12	0.12	0.04	9.97	9.95	9.96	9.97	9.98	0.04	0.06	0.09	0.10
Philadelphia, Pa.:												
8 a. m.	0.13	0.11	0.09	0.02	0.03	0.02	0.01	0.04	0.12	0.13	0.11	0.11
8 p. m.	0.11	0.08	0.06	9.98	9.99	9.98	9.97	0.01	0.08	0.10	0.09	0.10
Phoenix, Ariz.:												
8 a. m.	0.06	0.02	9.96	9.88	9.81	9.77	9.81	9.82	9.83	9.91	0.00	0.06
8 p. m.	0.03	9.97	9.90	9.80	9.72	9.67	9.70	9.72	9.74	9.84	9.96	0.02
Pierre, S. Dak.:												
8 a. m.	0.15	0.20	0.08	0.02	9.95	9.93	9.96	9.98	0.01	0.06	0.12	0.14
8 p. m.	0.15	0.18	0.04	9.96	9.88	9.87	9.89	9.91	9.96	0.02	0.10	0.13

* Values interpolated.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Con.

Stations	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
UNITED STATES—con.												
Pittsburgh, Pa.:												
8 a. m.	0.11	0.11	0.08	0.02	0.02	0.02	0.02	0.04	0.11	0.13	0.12	0.12
8 p. m.	0.10	0.09	0.05	9.98	9.97	9.97	9.97	9.99	0.07	0.09	0.10	0.10
Pocatello, Idaho:												
8 a. m.	0.17	0.13	0.03	9.97	9.90	9.92	9.93	9.95	9.99	0.09	0.16	0.20
8 p. m.	0.16	0.11	0.00	9.92	9.84	9.85	9.85	9.87	9.93	0.05	0.14	0.19
Point Reyes, Calif.:												
*8 a. m.	0.05	0.03	9.99	9.98	9.93	9.91	9.92	9.92	9.92	9.98	0.05	0.08
8 p. m.	0.02	0.01	9.98	9.98	9.93	9.91	9.91	9.90	9.90	9.96	0.03	0.05
Port Angeles, Wash.:												
*8 a. m.	0.00	0.02	0.03	0.06	0.04	0.06	0.07	0.05	0.03	0.06	0.01	0.01
8 p. m.	9.98	9.98	9.98	0.04	0.02	0.05	0.05	0.04	0.02	0.05	9.99	0.01
Port Arthur, Tex.:												
*8 a. m.	0.15	0.12	0.08	0.02	9.98	9.99	0.02	0.01	0.00	0.06	0.14	0.14
*8 p. m.	0.14	0.10	0.04	9.97	9.94	9.94	9.98	9.96	9.96	0.03	0.11	0.11
Port Huron, Mich.:												
8 a. m.	0.07	0.09	0.05	0.01	0.01	0.00	0.00	0.03	0.08	0.08	0.06	0.06
8 p. m.	0.07	0.08	0.04	9.99	9.97	9.97	9.96	9.99	0.05	0.06	0.05	0.06
Portland, Me.:												
8 a. m.	0.05	0.00	0.02	9.98	9.99	9.99	9.97	0.03	0.09	0.08	0.02	0.03
8 p. m.	0.04	9.98	9.99	9.96	9.97	9.96	9.94	0.01	0.06	0.06	0.00	0.02
Portland, Oreg.:												
8 a. m.	0.06	0.05	0.04	0.08	0.05	0.06	0.05	0.04	0.02	0.08	0.06	0.09
8 p. m.	0.05	0.03	0.01	0.03	0.01	0.01	9.98	9.98	9.98	0.06	0.05	0.09
Providence, R. I.:												
8 a. m.	0.09	0.05	0.04	0.00	0.00	0.00	9.99	0.03	0.10	0.10	0.05	0.05
8 p. m.	0.06	0.01	0.01	9.97	9.97	9.96	9.95	0.01	0.07	0.07	0.02	0.04
Pueblo, Colo.:												
8 a. m.	0.07	0.07	9.98	9.94	9.89	9.91	9.96	9.98	0.00	0.06	0.11	0.10
8 p. m.	0.05	0.02	9.92	9.85	9.78	9.80	9.87	9.89	9.91	9.99	0.07	0.08
Raleigh, N. C.:												
8 a. m.	0.16	0.14	0.12	0.05	0.04	0.02	0.04	0.04	0.10	0.13	0.16	0.15
8 p. m.	0.14	0.09	0.07	9.99	9.98	9.97	9.99	0.00	0.06	0.09	0.12	0.13
Rapid City, S. Dak.:												
8 a. m.	0.13	0.18	0.07	0.03	9.96	9.95	9.98	0.00	0.02	0.08	0.12	0.13
8 p. m.	0.14	0.17	0.06	9.98	9.92	9.90	9.93	9.95	9.98	0.06	0.12	0.14
Reading, Pa.:												
*8 a. m.	0.12	0.10	0.09	0.02	0.02	0.02	0.02	0.04	0.12	0.13	0.11	0.11
8 p. m.	0.11	0.08	0.05	9.98	9.98	9.98	9.97	0.00	0.08	0.10	0.09	0.11
Red Bluff, Calif.:												
8 a. m.	0.11	0.06	0.03	0.02	9.95	9.90	9.87	9.88	9.91	0.01	0.11	0.15
8 p. m.	0.08	0.04	0.00	9.95	9.87	9.82	9.79	9.80	9.84	9.95	0.04	0.12
Reno, Nev.:												
8 a. m.	0.12	0.08	0.03	9.98	9.91	9.91	9.92	9.92	9.94	0.06	0.15	0.16
8 p. m.	0.10	0.04	9.98	9.92	9.85	9.83	9.84	9.84	9.87	9.99	0.11	0.13
Richmond, Va.:												
8 a. m.	0.16	0.14	0.11	0.04	0.04	0.03	0.03	0.05	0.12	0.14	0.15	0.15
8 p. m.	0.12	0.09	0.06	9.99	9.98	9.98	9.99	0.01	0.08	0.10	0.11	0.12
Rochester, N. Y.:												
8 a. m.	0.07	0.07	0.06	0.01	0.02	0.01	0.00	0.04	0.10	0.10	0.07	0.06
8 p. m.	0.07	0.06	0.05	9.99	9.98	9.97	9.96	0.00	0.07	0.08	0.05	0.06
Roseburg, Oreg.:												
8 a. m.	0.08	0.06	0.06	0.10	0.06	0.07	0.04	0.04	0.03	0.10	0.10	0.13
8 p. m.	0.06	0.03	0.02	0.04	0.01	0.00	9.97	9.95	9.98	0.04	0.08	0.11
Roswell, N. Mex.:												
8 a. m.	0.10	0.06	9.99	9.91	9.86	9.88	9.94	9.95	9.98	0.03	0.11	0.10
8 p. m.	0.05	9.99	9.90	9.80	9.74	9.76	9.83	9.85	9.88	9.95	0.04	0.05
Royal Center, Ind.:												
*8 a. m.	0.12	0.13	0.07	0.01	0.01	0.01	0.02	0.03	0.09	0.10	0.10	0.11
*8 p. m.	0.10	0.11	0.05	9.99	9.96	9.96	9.97	9.99	0.05	0.07	0.09	0.10
Sacramento, Calif.:												
8 a. m.	0.12	0.07	0.04	0.01	9.94	9.89	9.88	9.88	9.91	9.99	0.10	0.14
8 p. m.	0.09	0.05	0.01	9.97	9.91	9.85	9.84	9.84	9.86	9.96	0.06	0.12
Saginaw, Mich.:												
*8 a. m.	0.06	0.08	0.05	0.01	0.01	0.01	0.00	0.03	0.08	0.07	0.05	0.06
*8 p. m.	0.06	0.07	0.04	9.99	9.97	9.97	9.96	9.98	0.05	0.05	0.04	0.05
St. Joseph, Mo.:												
*8 a. m.	0.14	0.14	0.05	9.99	9.94	9.96	9.98	9.98	0.04	0.07	0.11	0.12
*8 p. m.	0.13	0.13	0.02	9.94	9.90	9.90	9.91	9.93	9.98	0.04	0.09	0.11
St. Louis, Mo.:												
8 a. m.	0.13	0.13	0.06	0.00	9.98	9.99	0.00	0.02	0.07	0.09	0.12	0.12
8 p. m.	0.12	0.11	0.02	9.96	9.92	9.93	9.94	9.96	0.01	0.06	0.10	0.10
St. Paul, Minn.:												
8 a. m.	0.10	0.14	0.04	0.00	9.96	9.95	9.97	0.00	0.02	0.03	0.06	0.08
8 p. m.	0.09	0.12	0.02	9.95	9.91	9.91	9.93	9.95	9.98	0.00	0.04	0.06
Salt Lake City, Utah:												
8 a. m.	0.14	0.09	0.00	9.94	9.86	9.87	9.90	9.92	9.95	0.06	0.13	0.17
8 p. m.	0.14	0.07	9.97	9.89	9.81	9.82	9.83	9.86	9.90	0.02	0.11	0.16
San Antonio, Tex.:												
8 a. m.	0.14	0.11	0.04	9.98	9.93	9.95	9.99	9.98	9.99	0.05	0.12	0.13
8 p. m.	0.10	0.05	9.97	9.89	9.84	9.86	9.90	9.89	9.91	9.99	0.07	0.09
San Diego, Calif.:												
8 a. m.	0.06	0.04	0.02	9.97	9.93	9.90	9.90	9.90	9.89	9.94	0.02	0.05
8 p. m.	0.05	0.03	0.01	9.96	9.93	9.88	9.88	9.88	9.87	9.92	9.99	0.04
Sand Key, Fla.:												
*8 a. m.	0.10	0.09	0.07	0.01	9.97	9.98	0.02	0.01	9.94	9.95	0.04	0.07
*8 p. m.	0.09	0.06	0.04	9.99	9.95	9.96	0.01	9.99	9.94	9.93	0.02	0.06
Sandusky, Ohio:												
8 a. m.	0.09	0.10	0.06	0.01	0.01	0.00	0.00	0.03	0.09	0.10	0.09	0.09
8 p. m.	0.09	0.09	0.05	9.98	9.97	9.97	9.96	9.98	0.06	0.08	0.07	0.09
Sandy Hook, N. J.:												
*8 a. m.	0.10	0.07	0.07	0.00	0.01	0.01	0.00	0.03	0.10	0.11	0.09	0.09
*8 p. m.	0.09	0.06	0.04	9.96	9.97	9.97	9.97	0.00	0.07	0.09	0.07	0.08
San Francisco, Calif.:												
8 a. m.	0.11	0.08	0.06	0.04	9.99	9.96	9.96	9.96	9.96	0.02	0.11	0.13
8 p. m.	0.07	0.06	0.04	0.03	9.98	9.95	9.94	9.93	9.93	9.99	0.08	0.09
San Jose, Calif.:												
*8 a. m.	0.13	0.09	0.07	0.04	0.00	9.97	9.96	9.95	9.96	0.02	0.11	0.15
8 p. m.	0.10	0.07	0.05	0.02	9.98	9.95	9.93	9.92	9.93	9.99	0.08	0.12

* Values interpolated.

88731—24——3

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Con.

Stations	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
UNITED STATES—con.												
San Luis Obispo, Calif.:												
8 a. m.	0.11	0.09	0.06	0.04	9.99	9.96	9.96	9.96	9.95	0.01	0.08	0.12
8 p. m.	0.09	0.07	0.04	0.02	9.98	9.94	9.94	9.93	9.92	9.98	0.06	0.09
Santa Fe, N. Mex.:												
8 a. m.	0.12	0.04	9.97	9.89	9.82	9.84	9.91	9.93	9.95	0.02	0.11	0.13
8 p. m.	0.11	0.02	9.92	9.83	9.75	9.76	9.84	9.86	9.89	9.98	0.09	0.12
Sault Ste. Marie, Mich.:												
8 a. m.	0.04	0.08	0.06	0.02	0.01	0.00	9.98	0.01	0.06	0.04	0.01	0.03
8 p. m.	0.03	0.07	0.04	0.00	9.98	9.96	9.95	9.98	0.03	0.03	0.01	0.02
Savannah, Ga.:												
8 a. m.	0.18	0.14	0.12	0.07	0.04	0.03	0.06	0.05	0.06	0.10	0.16	0.16
8 p. m.	0.15	0.11	0.08	0.02	0.00	9.99	0.02	0.01	0.03	0.07	0.12	0.14
Scranton, Pa.:												
8 a. m.	0.10	0.09	0.08	0.02	0.02	0.02	0.02	0.04	0.12	0.13	0.10	0.09
8 p. m.	0.10	0.07	0.05	9.97	9.97	9.97	9.97	0.01	0.08	0.09	0.07	0.08
Seattle, Wash.:												
8 a. m.	0.04	0.05	0.03	0.08	0.06	0.08	0.08	0.07	0.05	0.09	0.04	0.07
8 p. m.	0.04	0.03	0.02	0.06	0.03	0.04	0.04	0.04	0.02	0.08	0.04	0.07
Sheridan, Wyo.:												
*8 a. m.	0.14	0.16	0.08	0.01	9.94	9.94	9.99	0.01	0.03	0.09	0.14	0.16
*8 p. m.	0.12	0.14	0.02	9.96	9.89	9.88	9.92	9.93	9.98	0.07	0.13	0.13
Shreveport, La.:												
8 a. m.	0.17	0.15	0.09	0.03	9.99	9.99	0.02	0.01	0.04	0.10	0.17	0.16
8 p. m.	0.14	0.10	0.02	9.96	9.91	9.92	9.95	9.95	9.97	0.05	0.12	0.13
Sioux City, Iowa:												
8 a. m.	0.14	0.16	0.05	0.00	9.94	9.94	9.97	9.99	0.03	0.06	0.10	0.12
*8 p. m.	0.14	0.15	0.03	9.95	9.88	9.88	9.91	9.93	9.97	0.03	0.09	0.12
Spokane, Wash.:												
8 a. m.	0.11	0.11	0.02	0.02	9.97	9.97	9.96	9.98	0.01	0.10	0.11	0.14
8 p. m.	0.10	0.08	9.99	9.98	9.92	9.92	9.90	9.92	9.96	0.06	0.10	0.14
Springfield, Ill.:												
8 a. m.	0.12	0.12	0.05	0.00	9.97	9.98	0.00	0.01	0.06	0.08	0.10	0.11
8 p. m.	0.11	0.11	0.02	9.95	9.92	9.92	9.94	9.96	0.01	0.05	0.09	0.10
Springfield, Mo.:												
8 a. m.	0.13	0.12	0.06	0.00	9.97	9.99	0.02	0.02	0.07	0.10	0.13	0.13
8 p. m.	0.12	0.10	0.02	9.95	9.91	9.93	9.96	9.96	0.01	0.06	0.10	0.11
Syracuse, N. Y.:												
8 a. m.	0.07	0.08	0.06	0.00	0.01	0.01	0.00	0.04	0.10	0.09	0.06	0.06
*8 p. m.	0.07	0.06	0.04	9.97	9.96	9.96	9.95	0.00	0.07	0.07	0.05	0.06
Tacoma, Wash.:												
8 a. m.	0.04	0.04	0.03	0.08	0.06	0.07	0.07	0.07	0.04	0.09	0.05	0.08
*8 p. m.	0.04	0.03	0.02	0.06	0.02	0.03	0.03	0.02	0.00	0.06	0.03	0.04
Tampa, Fla.:												
8 a. m.	0.16	0.14	0.12	0.06	0.02	0.02	0.06	0.04	0.00	0.03	0.12	0.14
8 p. m.	0.14	0.11	0.08	0.02	9.98	9.98	0.03	0.01	9.97	0.00	0.09	0.12
Tatoosh Island, Wash.:												
8 a. m.	9.95	9.99	9.97	0.04	0.03	0.04	0.06	0.04	0.01	0.03	9.97	9.97
8 p. m.	9.94	9.98	9.98	0.05	0.05	0.06	0.08	0.06	0.01	0.03	9.97	9.97
Taylor, Tex.:												
8 a. m.	0.16	0.13	0.06	9.99	9.95	9.97	0.01	0.00	0.02	0.06	0.13	0.15
*8 p. m.	0.11	0.06	9.98	9.90	9.86	9.89	9.91	9.90	9.94	0.00	0.09	0.10
Terre Haute, Ind.:												
*8 a. m.	0.14	0.13	0.08	0.01	0.00	0.01	0.01	0.03	0.09	0.10	0.14	0.13
*8 p. m.	0.12	0.11	0.05	9.99	9.95	9.95	9.96	9.98	0.04	0.07	0.10	0.11
Thomasville, Ga.:												
*8 a. m.	0.17	0.15	0.12	0.06	0.03	0.03	0.05	0.05	0.05	0.09	0.16	0.16
8 p. m.	0.15	0.11	0.08	0.01	9.98	9.98	0.01	0.00	0.00	0.05	0.12	0.13
Titusville, Fla.:												
*8 a. m.	0.16	0.13	0.11	0.06	0.03	0.03	0.06	0.04	0.02	0.04	0.12	0.14
*8 p. m.	0.14	0.11	0.08	0.02	9.99	9.99	0.03	0.02	0.00	0.02	0.09	0.12
Toledo, Ohio:												
8 a. m.	0.10	0.11	0.07	0.02	0.01	0.01	0.01	0.04	0.10	0.11	0.10	0.09
8 p. m.	0.09	0.10	0.05	9.98	9.97	9.96	9.96	9.99	0.06	0.08	0.08	0.09
Tonopah, Nev.:												
8 a. m.	0.12	0.07	9.99	9.92	9.86	9.87	9.92	9.92	9.93	0.02	0.12	0.16
8 p. m.	0.10	0.04	9.95	9.86	9.80	9.80	9.83	9.84	9.87	9.97	0.08	0.13
Trenton, N. J.:												
*8 a. m.	0.11	0.09	0.08	0.01	0.02	0.02	0.00	0.03	0.11	0.12	0.10	0.10
*8 p. m.	0.10	0.07	0.05	9.97	9.98	9.98	9.97	0.00	0.08	0.10	0.09	0.10
Valentine, Nebr.:												
8 a. m.	0.13	0.16	0.05	0.00	9.94	9.94	9.97	9.99	0.02	0.06	0.11	0.12
8 p. m.	0.12	0.15	0.03	9.95	9.88	9.88	9.92	9.93	9.97	0.03	0.10	0.12
Vicksburg, Miss.:												
8 a. m.	0.18	0.16	0.11	0.05	0.02	0.02	0.05	0.03	0.05	0.11	0.18	0.17
8 p. m.	0.15	0.12	0.05	9.98	9.95	9.95	9.98	9.98	9.99	0.06	0.13	0.14
Walla Walla, Wash.:												
8 a. m.	0.12	0.11	0.03	0.04	9.99	9.99	9.97	9.98	0.00	0.09	0.11	0.16
8 p. m.	0.11	0.08	0.00	9.98	9.92	9.91	9.88	9.90	9.95	0.05	0.10	0.15
Washington, D. C.:												
8 a. m.	0.14	0.13	0.10	0.03	0.03	0.02	0.01	0.04	0.11	0.13	0.13	0.13
8 p. m.	0.12	0.09	0.06	9.97	9.97	9.97	9.96	0.00	0.07	0.09	0.10	0.12
Wausau, Wis.:												
*8 a. m.	0.08	0.11	0.04	0.01	9.99	9.98	9.98	0.00	0.04	0.03	0.04	0.06
*8 p. m.	0.07	0.09	0.02	9.97	9.94	9.94	9.94	9.96	0.01	0.01	0.03	0.05
Wichita, Kans.:												
8 a. m.	0.14	0.14	0.05	9.98	9.93	9.95	9.98	9.98	0.03	0.07	0.12	0.14
8 p. m.	0.13	0.11	0.00	9.92	9.87	9.88	9.90	9.91	9.96	0.03	0.09	0.12
Williston, N. Dak.:												
8 a. m.	0.10	0.16	0.05	0.00	9.93	9.91	9.93	9.95	9.98	0.02	0.05	0.08
8 p. m.	0.10	0.15	0.03	9.96	9.88	9.86	9.88	9.89	9.93	9.99	0.04	0.07
Wilmington, N. C.:												
8 a. m.	0.17	0.14	0.12	0.06	0.04	0.03	0.05	0.04	0.08	0.11	0.15	0.15
8 p. m.	0.14	0.10	0.08	0.01	0.00	9.99	0.01	0.01	0.05	0.08	0.12	0.13
Winnemucca, Nev.:												
8 a. m.	0.16	0.09	0.03	0.00	9.93	9.94	9.95	9.96	0.00	0.10	0.16	0.20
8 p. m.	0.14	0.06	9.98	9.93	9.86	9.85	9.84	9.87	9.92	0.06	0.13	0.18

* Values interpolated.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Con.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
UNITED STATES—con.												
Wytheville, Va.:												
8 a. m.	0.14	0.14	0.11	0.04	0.04	0.03	0.04	0.06	0.13	0.15	0.17	0.15
8 p. m.	0.14	0.12	0.08	0.00	9.99	9.99	0.00	0.02	0.09	0.12	0.15	0.14
Yakima, Wash.:												
*8 a. m.	0.07	0.08	0.03	0.05	0.02	0.04	0.00	0.01	0.01	0.08	0.08	0.11
*8 p. m.	0.06	0.05	0.01	0.02	9.97	9.96	9.90	9.95	9.97	0.06	0.07	0.10
Yankton, S. Dak.:												
8 a. m.	0.14	0.17	0.06	0.00	9.94	9.94	9.97	9.98	0.02	0.06	0.11	0.12
*8 p. m.	0.14	0.15	0.04	9.95	9.89	9.90	9.92	9.93	9.98	0.03	0.09	0.13
Yellowstone Park, Wyo.:												
8 a. m.	0.14	0.14	0.06	0.00	9.94	9.95	0.02	0.02	0.04	0.12	0.18	0.19
8 p. m.	0.13	0.11	0.02	9.95	9.88	9.88	9.94	9.94	9.98	0.08	0.16	0.18
Yuma, Ariz.:												
8 a. m.	0.06	0.01	9.96	9.88	9.80	9.75	9.77	9.79	9.80	9.89	0.00	0.06
8 p. m.	0.03	9.98	9.92	9.82	9.74	9.68	9.70	9.71	9.73	9.84	9.96	0.03
CANADA.												
Anticosti Island, southwest pt. Que.:												
8 a. m.	9.89	9.84	9.89	9.91	9.91	9.91	9.86	9.91	9.96	9.93	9.88	9.87
8 p. m.	9.87	9.83	9.88	9.91	9.91	9.89	9.85	9.90	9.95	9.93	9.87	9.85
Atlin, B. C.:												
8 a. m.	0.04	0.08	0.00	9.96	0.00	0.01	0.05	0.03	9.92	9.87	9.81	9.88
8 p. m.	0.04	0.03	9.94	9.91	9.95	9.96	9.99	9.99	9.89	9.85	9.80	9.87
Banff, Alb.:												
8 a. m.	0.08	0.11	0.01	9.99	9.96	9.94	9.99	0.01	0.01	0.04	0.04	0.08
8 p. m.	0.07	0.07	9.96	9.93	9.90	9.89	9.92	9.93	9.95	0.00	0.03	0.06
Barkerville, B. C.:												
8 a. m.	9.94	9.97	9.91	9.94	9.95	9.97	0.02	0.04	0.00	9.99	9.92	9.94
8 p. m.	9.93	9.95	9.89	9.90	9.91	9.95	9.99	0.01	9.97	9.96	9.91	9.93
Battleford, Sask.:												
8 a. m.												
8 p. m.												
Bermuda:												
8 a. m.	0.16	0.12	0.14	0.09	0.11	0.13	0.18	0.14	0.08	0.07	0.08	0.12
8 p. m.	0.16	0.11	0.13	0.09	0.11	0.13	0.18	0.14	0.08	0.07	0.07	0.12
Calgary, Alb.:												
8 a. m.	0.02	0.07	9.97	9.94	9.91	9.89	9.93	9.94	9.94	9.97	9.97	9.99
8 p. m.	0.03	0.06	9.95	9.89	9.86	9.84	9.86	9.90	9.90	9.94	9.96	9.99
Charlottetown, P. E. I.:												
8 a. m.	9.97	9.90	9.94	9.94	9.96	9.96	9.93	9.99	0.03	0.02	9.94	9.92
8 p. m.	9.95	9.88	9.93	9.94	9.96	9.95	9.92	9.98	0.02	0.01	9.92	9.91
Chatham, N. B.:												
8 a. m.	0.00	9.93	9.97	9.95	9.96	9.95	9.92	9.98	0.04	0.02	9.97	9.96
8 p. m.	9.97	9.90	9.94	9.94	9.94	9.93	9.89	9.96	0.01	0.00	9.94	9.94
Cochrane, Ontario:												
8 a. m.	0.08	0.09	0.11	0.06	0.02	9.99	9.95	9.98	0.06	0.02	0.03	0.09
8 p. m.	0.06	0.08	0.07	0.03	9.98	9.35	9.92	9.95	0.02	0.01	0.02	0.08
Dawson, Y. T.:												
8 a. m.	0.26	0.20	0.13	9.96	9.91	9.91	9.93	9.92	9.90	9.87	9.96	0.05
8 p. m.	0.26	0.17	0.06	9.89	9.86	9.85	9.88	9.86	9.84	9.85	9.95	0.04
Edmonton, Alb.:												
8 a. m.	0.03	0.08	9.98	9.94	9.89	9.88	9.90	9.92	9.93	9.93	9.94	9.98
8 p. m.	0.02	0.06	9.94	9.86	9.84	9.83	9.86	9.88	9.89	9.91	9.93	9.97
Father Point, Que.:												
8 a. m.	9.99	9.93	9.96	9.94	9.94	9.93	9.88	9.94	0.01	9.98	9.94	9.97
8 p. m.	9.97	9.92	9.93	9.92	9.91	9.89	9.85	9.91	9.97	9.97	9.94	9.96
Halifax, N. S.:												
8 a. m.	9.98	9.91	9.96	9.93	9.97	9.97	9.95	0.01	0.05	0.04	9.95	9.95
8 p. m.	9.96	9.89	9.94	9.93	9.96	9.96	9.94	0.00	0.04	0.02	9.93	9.93
Harrington Harbor, Que.:												
8 a. m.	9.77	9.74	9.81	9.90	9.91	9.93	9.91	9.91	9.92	9.94	9.85	9.83
8 p. m.	9.78	9.76	9.81	9.90	9.91	9.91	9.90	9.90	9.90	9.93	9.85	9.80
Kamloops, B. C.:												
8 a. m.	0.06	0.06	9.95	9.96	9.93	9.93	9.95	9.96	9.97	0.02	9.99	0.04
8 p. m.	0.05	0.02	9.90	9.89	9.83	9.84	9.84	9.86	9.89	9.97	9.97	0.03
Kingston, Ont.:												
8 a. m.	0.08	0.07	0.05	0.00	9.99	9.98	9.96	0.01	0.08	0.07	0.04	0.06
8 p. m.	0.07	0.05	0.03	9.97	9.95	9.94	9.92	9.97	0.04	0.05	0.03	0.05
Le Pas, Man.:												
8 a. m.	0.14	0.19	0.11	0.03	9.97	9.89	9.86	9.91	9.97	9.98	9.98	0.10
8 p. m.	0.14	0.16	0.09	0.01	9.92	9.87	9.84	9.87	9.94	9.97	9.98	0.10
Medicine Hat, Alb.:												
8 a. m.	0.04	0.09	9.98	9.93	9.88	9.86	9.89	9.91	9.94	9.97	9.97	0.00
8 p. m.	0.04	0.07	9.95	9.88	9.83	9.80	9.84	9.86	9.89	9.93	9.96	0.00
Minnedosa, Man.:												
8 a. m.	0.09	0.16	0.06	0.03	9.97	9.92	9.93	9.96	9.98	9.99	0.02	0.06
8 p. m.	0.10	0.15	0.05	0.01	9.93	9.88	9.90	9.93	9.96	9.99	0.02	0.06
Montreal, Que.:												
8 a. m.	0.05	0.03	0.02	9.97	9.96	9.95	9.93	9.99	0.06	0.05	0.01	0.04
8 p. m.	0.03	0.00	9.99	9.94	9.92	9.90	9.89	9.95	0.02	0.02	9.99	0.02
New Westminster, B. C.:												
8 a. m.	0.03	9.99	9.97	0.06	0.02	0.02	0.03	0.04	0.03	0.05	9.98	0.05
8 p. m.	0.03	9.98	9.96	0.04	0.00	0.01	0.02	0.02	0.02	0.05	9.98	0.05
Ottawa, Ont.:												
8 a. m.	0.07	0.06	0.03	9.98	9.98	9.97	9.95	0.00	0.07	0.07	0.04	0.06
8 p. m.	0.05	0.03	0.00	9.94	9.92	9.91	9.90	9.95	0.02	0.03	0.01	0.04
Parry Sound, Ont.:												
8 a. m.	0.03	0.06	0.04	0.00	9.99	9.99	9.97	0.01	0.06	0.06	0.02	0.03
8 p. m.	0.03	0.04	0.01	9.96	9.95	9.94	9.93	9.97	0.03	0.03	0.00	0.02
Port Arthur, Ont.:												
8 a. m.	0.06	0.11	0.06	0.04	0.01	9.98	9.96	9.99	0.02	0.00	0.01	0.04
8 p. m.	0.05	0.08	0.02	0.00	9.97	9.94	9.93	9.96	9.99	9.99	0.00	0.04

* Values interpolated.

Pressure at sea level, 8 a. m. and 8 p. m., 75th meridian time—Con.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
CANADA—continued.												
Port Simpson, B. C.:												
8 a. m.	9.84	9.84	9.85	9.96	9.99	9.99	0.05	0.00	9.92	9.88	9.77	9.78
8 p. m.	9.83	9.83	9.86	9.97	9.98	0.00	0.01	0.01	9.90	9.90	9.77	9.78
Port Stanley, Ont.:												
8 a. m.	0.09	0.11	0.06	0.01	0.01	0.00	9.99	0.02	0.09	0.09	0.07	0.07
8 p. m.	0.09	0.10	0.05	9.99	9.97	9.96	9.95	9.97	0.05	0.07	0.06	0.08
Prince Albert, Sask.:												
8 a. m.												
8 p. m.												
Prince Rupert, B. C.:												
8 a. m.	9.79	9.88	9.86	9.94	9.96	0.02	0.03	0.02	9.94	9.88	9.76	9.78
8 p. m.	9.79	9.88	9.86	9.94	9.96	0.02	0.04	0.03	9.93	9.88	9.75	9.78
Qu'Appelle, Sask.:												
8 a. m.												
8 p. m.												
Quebec, Que.:												
8 a. m.	0.03	9.99	0.00	9.96	9.96	9.95	9.92	9.99	0.05	0.04	9.99	0.01
8 p. m.	0.02	9.97	9.97	9.94	9.92	9.90	9.88	9.95	0.02	0.01	9.98	0.00
Sable Island:												
8 a. m.	9.98	9.90	9.95	9.94	9.99	0.01	0.01	0.05	0.07	0.06	9.95	9.93
8 p. m.	9.96	9.88	9.95	9.94	9.99	0.00	0.00	0.04	0.06	0.04	9.93	9.92
St. John, N. B.:												
8 a. m.	0.01	9.94	9.97	9.95	9.96	9.96	9.95	0.00	0.06	0.04	9.97	9.97
8 p. m.	9.98	9.91	9.95	9.93	9.95	9.95	9.92	9.99	0.03	0.02	9.95	9.95
Southampton, Ont.:												
8 a. m.	0.02	0.06	0.04	0.00	0.00	0.00	9.95	0.03	0.07	0.06	0.02	0.01
8 p. m.	0.03	0.04	0.02	9.98	9.97	9.96	9.96	9.99	0.05	0.04	0.01	0.02
Stonecliff, Ont.:												
8 a. m.	0.07	0.07	0.05	0.01	9.99	9.97	9.95	0.01	0.07	0.06	0.02	0.05
8 p. m.	0.05	0.04	0.01	9.96	9.93	9.92	9.90	9.95	0.02	0.02	0.00	0.04
Swift Current, Sask.:												
8 a. m.												
8 p. m.												
Sydney, C. B. I.:												
8 a. m.	9.95	9.87	9.94	9.94	9.96	9.97	9.95	0.00	0.04	0.02	9.93	9.90
8 p. m.	9.93	9.87	9.94	9.95	9.97	9.97	9.96	0.00	0.03	0.02	9.92	9.89
Toronto, Ont.:												
8 a. m.	0.07	0.08	0.06	0.00	0.00	9.99	9.97	0.01	0.08	0.08	0.05	0.05
8 p. m.	0.06	0.07	0.04	9.98	9.96	9.95	9.94	9.98	0.05	0.05	0.04	0.05
Vancouver, B. C.:												
8 a. m.	9.99	0.04	0.03	0.06	0.03	0.04	0.05	0.04	0.02	0.07	0.05	0.02
8 p. m.	9.98	0.02	0.00	0.03	0.00	0.01	0.01	0.01	9.99	0.05	0.01	0.01
Victoria, B. C.:												
8 a. m.	9.99	0.00	9.99	0.04	0.02	0.03	0.04	0.03	0.01	0.05	9.99	0.02
8 p. m.	9.99	9.99	9.98	0.03	0.01	0.02	0.02	0.02	0.00	0.05	9.99	0.02
White River, Ont.:												
8 a. m.	0.02	0.06	0.04	0.01	9.99	9.95	9.92	9.97	0.01	0.00	9.98	0.00
8 p. m.	0.00	0.04	0.02	9.98	9.95	9.91	9.89	9.94	9.98	9.99	9.97	9.99
Winnipeg, Man.:												
8 a. m.	0.12	0.17	0.08	0.04	9.98	9.93	9.92	9.95	9.97	9.99	0.03	0.08
8 p. m.	0.12	0.16	0.06	0.01	9.93	9.88	9.89	9.92	9.94	9.98	0.03	0.07
Yarmouth, N. S.:												
8 a. m.	0.00	9.94	9.98	9.94	9.98	9.98	9.97	0.02	0.07	0.06	9.97	9.97
8 p. m.	9.98	9.92	9.96	9.94	9.97	9.97	9.96	0.01	0.05	0.04	9.96	9.95

Pressure at sea level, a. m. and p. m.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
ALASKA.[1]												
Akiak:												
a. m.	9.82	9.85	9.92	9.94	9.97	9.96	9.95	9.84	9.76	9.68	9.68	9.72
p. m.	9.80	9.82	9.89	9.92	9.96	9.93	9.92	9.83	9.75	9.67	9.67	9.71
Attu Island:												
a. m.	9.55	9.52	9.64	9.76	9.83	9.88	9.89	9.86	9.80	9.76	9.67	9.59
p. m.												
Dutch Harbor:												
a. m.	9.63	9.61	9.72	9.82	9.90	9.97	9.99	9.88	9.75	9.68	9.58	9.58
p. m.	9.64	9.62	9.74	9.83	9.92	9.99	0.02	9.90	9.76	9.69	9.59	9.58
Eagle:												
a. m.	0.11	0.07	9.98	9.88	9.87	9.87	9.86	9.84	9.82	9.83	9.90	0.00
p. m.	0.07	0.02	9.93	9.84	9.82	9.80	9.80	9.79	9.76	9.76	9.83	9.92
Juneau:												
a. m.	9.88	9.93	9.94	9.96	0.00	0.02	0.06	0.03	9.93	9.88	9.75	9.79
p. m.	9.89	9.92	9.93	9.95	9.98	0.00	0.04	0.02	9.91	9.86	9.76	9.79
Kodiak (a):												
a. m.	9.64	9.70	9.75	9.80	9.87	9.95	9.97	9.86	9.72	9.60	9.54	9.58
p. m.	9.64	9.70	9.75	9.80	9.87	9.94	9.96	9.85	9.70	9.59	9.54	9.58
Nome:												
a. m.	9.90	9.90	9.87	9.86	9.85	9.86	9.86	9.79	9.71	9.69	9.72	9.78
p. m.	9.88	9.88	9.86	9.86	9.85	9.88	9.88	9.80	9.73	9.69	9.71	9.76
Noorvik:												
a. m.	9.93	9.99	9.99	9.96	9.95	9.91	9.89	9.85	9.81	9.79	9.84	9.86
p. m.	9.91	9.98	9.97	9.94	9.92	9.89	9.87	9.83	9.78	9.76	9.80	9.83
St. Paul Island:												
a. m.	9.68	9.66	9.74	9.81	9.86	9.92	9.87	9.78	9.71	9.68	9.63	9.61
p. m.	9.69	9.66	9.75	9.80	9.86	9.89	9.85	9.76	9.70	9.66	9.62	9.61

[1] Most Alaskan and West Indian records are for too short periods to determine accurate normals, but the values for the shorter record stations have been corrected to harmonize as nearly as possible with the trend of the longer record stations.

Pressure at sea level, a. m. and p. m.—Continued.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
ALASKA—continued.												
Sitka:												
a. m	9.80	9.86	9.90	9.94	9.99	0.03	0.04	9.98	9.84	9.77	9.71	9.78
p. m	9.77	9.84	9.87	9.91	9.97	0.01	0.05	0.01	9.87	9.78	9.68	9.74
Tanana:												
a. m	0.08	0.06	0.05	9.99	9.95	9.92	9.88	9.83	9.80	9.73	9.82	9.94
p. m	0.07	0.06	0.02	9.97	9.92	9.87	9.83	9.77	9.75	9.70	9.81	9.93
Valdez:												
a. m	9.78	9.83	9.84	9.89	9.96	0.00	0.03	9.94	9.81	9.69	9.63	9.66
p. m	9.77	9.82	9.82	9.86	9.93	9.97	0.00	9.93	9.79	9.68	9.62	9.65
PACIFIC OCEAN.[2]												
Honolulu, Hawaii:												
a. m	0.01	0.06	0.05	0.07	0.06	0.05	0.03	0.02	0.00	0.01	0.03	0.02
p. m	9.99	0.04	0.04	0.06	0.04	0.03	0.01	0.00	9.99	0.00	0.02	0.00
Midway Island:												
a. m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
p. m	0.00	0.03	0.08	0.10	0 09	0.07	0.08	0.09	0.07	0.05	0.07	0.04

Pressure at sea level, 7 a. m. and 7 p. m., 75th meridian time.

Stations.	June.	July.	August.	September.	October.	November.
WEST INDIES.[2]						
Basseterre:						
7 a. m	0.00	0.03	9.99	9.95	9.93	9.95
7 p. m	9.98	0.01	9.97	9.94	9.91	9.93
Bridgetown:						
7 a. m	9.99	0.00	9.98	9.95	9.94	9.93
7 p. m	9.96	9.98	9.95	9.92	9.90	9.91
Camaguey:						
7 a. m	9.96	0.01	0.00	9.96	9.92	9.98
7 p. m	9.96	0.00	9.99	9.95	9.91	9.97
Curacao:						
7 a. m	9.89	9.92	9.90	9.86	9.86	9.86
7 p. m	9.86	9.87	9.85	9.80	9.80	9.83
Guantanamo:						
7 a. m	9.97	0.01	9.99	9.93	9.92	9.95
7 p. m	9.94	9.97	9.95	9.90	9.90	9.92
Habana:						
7 a. m	9.99	0.03	9.99	9.95	9.94	0.03
7 p. m	9.98	0.02	9.98	9.94	9.93	0.01
Kingston:						
7 a. m	9.93	9.97	9.95	9.91	9.89	9.92
7 p. m	9.92	9.94	9.92	9.88	9.86	9.90

[2] See footnote for Alaska.

Pressure at sea level, 7 a. m. and 7 p. m., 75th meridian time—Con.

Stations.	June.	July.	August.	September.	October.	November.
WEST INDIES—contd.						
Port-au-Prince:						
7 a. m	9.97	0.00	9.99	9.94	9.92	9.95
7 p. m	9.94	9.97	9.94	9.89	9.87	9.90
Port Castries:						
7 a. m	9.98	9.99	9.97	9.93	9.90	9.90
7 p. m	9.96	9.97	9.95	9.91	9.88	9.88
Port of Spain:						
7 a. m	9.95	9.98	9.96	9.94	9.92	9.91
7 p. m	9.89	9.91	9.88	9.86	9.84	9.84
Puerto Plata:						
7 a. m	0.01	0.05	0.04	9.95	9.96	9.98
7 p. m	9.98	0.01	0.00	9.92	9.90	9.93
Roseau:						
7 a. m	9.99	0.01	9.98	9.95	9.93	9.93
7 p. m	9.96	9.98	9.95	9.91	9.89	9.89
St. Thomas:						
7 a. m	0.02	0.04	0.01	9.95	9.94	9.95
7 p. m	0.01	0.04	0.00	9.93	9.93	9.95
San Juan:						
7 a. m	0.03	0.05	0.02	9.97	9.95	9.96
7 p. m	0.02	0.03	0.00	9.95	9.92	9.93
Santiago de Cuba:						
7 a. m	9.94	9.98	9.96	9.94	9.89	9.94
7 p. m	9.93	9.97	9.95	9.92	9.88	9.92
Santo Domingo:						
7 a. m	0.00	0.03	0.01	9.95	9.95	9.98
7 p. m	9.96	9.99	9.97	9.91	9.90	9.92
Swan Island:						
7 a. m	9.87	9.92	9.91	9.88	9.87	9.90
7 p. m	9.85	9.91	9.89	9.85	9.84	9.87
Turks Island:						
7 a. m	0.03	0.07	0.04	9.98	9.95	9.99
7 p. m	0.01	0.06	0.02	9.96	9.93	9.97
CENTRAL AMERICA.[2]						
Belize:						
7 a. m	9.90	9.95	9.93	9.90	9.88	9.95
7 p. m	9.88	9.92	9.90	9.86	9.85	9.92
Bluefields:						
7 a. m	9.87	9.89	9.89	9.88	9.87	9.90
7 p. m	9.82	9.86	9.85	9.82	9.79	9.82
PANAMA CANAL ZONE.[2]						
Balboa Heights:						
7 a. m	9.85	9.85	9.86	9.86	9.86	9.86
7 p. m	9.82	9.82	9.82	9.82	9.83	9.82
Colon:						
7 a. m	9.85	9.87	9.86	9.86	9.86	9.86
7 p. m	9.83	9.84	9.84	9.83	9.83	9.83

[2] See footnote for Alaska.

NOTES, ABSTRACTS, AND REVIEWS.

Otto Klotz, LL., D. D. Sc., 1852–1923.

The news of the death of Otto Klotz, Director of the Dominion Observatory, on December 28, 1923, as announced by the Department of the Interior, Ottawa, on January 10, 1924, is received with great regret by officials of the United States Weather Bureau, many of whom were personally acquainted with him. He was held in high esteem because of his many contributions to the sciences of astronomy, geodesy, and seismology.

WEATHER BUREAU STAFF MEETINGS.

Regular meetings of the staff of the Central Office of the Weather Bureau have been held during the autumn and winter of 1923–24 as nearly as possible at two-week intervals. This plan of staff meetings has been tried before in the Weather Bureau with indifferent success, presumably because the programs were not properly supervised. The present plan, however, has been very successful and much interest has been shown throughout the year, giving every indication that a continuance of the plan will be welcomed.

The meetings, which are limited in length to one hour, have been held at 11 a. m., on first and third Wednesdays of each month, and will continue through May, there being no meetings during the summer. The Chief of the Weather Bureau presides at the meetings, or, in case of his absence, the Assistant Chief. The program committee consists of Dr. W. J. Humphreys, chairman, Prof. A. J. Henry, Dr. H. H. Kimball, and Prof. C. F. Talman. The secretary is C. LeRoy Meisinger. The discussions are restricted to matters of general scientific interest, whether current meteorological literature of importance, researches conducted within the Bureau, or projects of a scientific character upon which the opinion of the staff is desired. It is the desire to make these meetings of general helpfulness to field officials of the Weather Bureau through the discussion of matters that these officials may wish to bring to the attention of the Central Office group, or upon which the opinion of this group is desired. It is understood, of course, that such opinions are not final and conclusive.

The following is a list of the discussions that have been held:

NOVEMBER 13, 1923.

C. L. Mitchell: Aerological aids in forecasting the unusual movement of the Atlantic coast storm of October 23, 1923.

A. J. Henry: Variations in the levels of the central African lakes Victoria and Albert.[1] (Based on *Geophysical Memoirs, No. 20,* by C. E. P. Brooks.)

H. H. Kimball: On the variations of the sun's visible features associated with variations of solar radiation. (Based on paper of same title in *Proceedings of the National Academy of Sciences,* October, 1923, by C. G. Abbot.)

NOVEMBER 21, 1923.

W. J. Humphreys: Recent studies of the composition of the upper air.

C. LeRoy Meisinger: The mechanism of cyclones and anticyclones.[2] (Based on paper of same title in *Quarterly Journal of the Royal Meteorological Society,* July, 1923, by T. Kobayasi.)

F. G. Tingley: Further discussion of a proposed method of extrapolation of weather data, with a possible application to long-range forecasting.

DECEMBER 5, 1923.

A. J. Henry: Pacific LOWS and weather forecasting on the Pacific coast.

DECEMBER 19, 1923.

I. F. Hand: Investigation of the dust content of the atmosphere.[3]

S. P. Fergusson: Cloud systems. (Based on a memoir by Ph. Schreschewsky and Ph. Wehrlé of the Office National Météorologique de France.)

JANUARY 9, 1924.

O. L. Fassig (visiting official from San Juan, P. R.): Pilot-balloon work in Porto Rico.[4]

JANUARY 23, 1924.

C. F. Talman: An inspection of the Weather Bureau Library.

FEBRUARY 13, 1924.

E. W. Woolard: On the kinematics of an ideal cyclone.[5] (Based on a report of V. H. Ryd entitled "Travelling Cyclones." *Publikationer fra det Danske Meterologiske Institut,* Meddeleser Nr. 5, Copenhagen, 1923.)

FEBRUARY 20, 1924.

C. LeRoy Meisinger: The balloon project and what we hope to accomplish.[6]

H. W. Clough: A short cycle in terrestrial weather and its relation to solar data.[7]

A later issue of the REVIEW will contain programs for the remainder of the season.—*C. L. M.*

V. H. RYD ON TRAVELLING CYCLONES.[8]

By EDGAR W. WOOLARD.

[Weather Bureau, Washington, D. C., Feb. 13, 1924.]

In our efforts to explain natural phenomena and to construct comprehensive quantitative theories whereby what we have observed in the past is accurately described and what we shall observe in the future may be satisfactorily predicted, we are much handicapped by the extreme complexity of the actual conditions as found in Nature. In order that a problem may be handled at all by methods now available, it is almost always necessary to make "simplifying assumptions," i. e., to replace the intractable natural reality by a conceptual ideal; and it is to the latter that our subsequent discussion always applies. These assumptions are of such a character that the conditions subjected to theoretical investigation, while different from what we must assume to actually exist in Nature, are in general not so different that the results have no value as an indication of what may be conceived to happen in the natural reality.

It is sometimes necessary, however, to proceed by successive approximation, particularly at the start of an attack upon an especially complex problem. If an attempt be made to deal with *all* the complications of the natural reality, simultaneously and at the very beginning, no progress whatever may be possible; but by constructing successive workable ideals, each departing less and less from the natural reality, and noting carefully to what extent each suffices as a representation of what is observed actually to occur, a complete and satisfactory theory may eventually be worked out.

In Dynamical Meteorology not only are the problems involved extraordinarily complex, but we are at present handicapped by a lack of adequate observational data upon which to base the initial conceptual ideal, and whereby to check our resulting theories. However, the major features of actual phenomena are coming to be more and more satisfactorily represented in the theories of successive investigators. V. H. Ryd, of the Danish Meteorological Institute, to whom we owe a recent noteworthy attack on the problem of the circulation of the air in a cyclone, the source of the energy necessary for its maintenance, and the disposal of the rising air, states that "No theory of atmospheric mechanism can be proved directly, but the proof can be established gradually in an indirect manner. As a rule, the abundant explanations of meteorological phenomena from earlier days are based upon qualitative considerations only, but it might be difficult to set forth a theory so absurd that it could not be 'proved' in this manner. What can be done, and what ought to be done, is the making of *numerical computations by which it can be seen if the theory set forth is a probable one.* But, beyond this, the proof must rest with comparison with what is found in nature."

"If all the cases agree to a satisfactory degree, where such comparisons can be made, the theory must be taken as a true one for the present, and then without any hesitation we shall use conclusions drawn also where no comparison with facts can take place. On the contrary, when the theory disagrees with nature, it will depend on the special circumstances what is to be done. If the disagreement concerns the *foundation* itself, the theory must be considered as *a false one,* and it will be necessary to *abandon* it. On the other hand, if the disagreement concerns certain conclusions drawn from the theory, a new investigation can be made, and perhaps the result will be satisfactory when, for example, new circumstances are taken into consideration." Ryd deduces a theory of the pressure distributions and wind velocities at different levels in the cyclone, of the vertical circulation of the air at these levels, etc., and combines them into a description of the circulation of the air and the general mechanism of a travelling cyclone, illustrating and supporting his theory by a complete, worked out numerical example.[9]

[1] Discussion to appear in later REVIEW.
[2] This REVIEW, p. 37-38.
[3] To be discussed in a later REVIEW.
[4] This REVIEW, p. 22-26.
[5] This REVIEW, p. 36-37.
[6] This REVIEW, p. 27-29.
[7] This REVIEW, p. 38-39.
[8] Presented before the Weather Bureau Staff at its meeting of Feb. 13, 1924.

[9] Ryd, V. H.: Travelling Cyclones. *Publikationer fra det Danske Meteorologiske Institut, Meddelelser Nr. 5. Copenhagen, 1923.*

The cyclone considered is an ideal one, with circular isobars so spaced that the pressure distribution is amenable to mathematical expression and yet similar to what is often observed in real cyclones, superposed upon, and moving with uniform speed in a straight line through, a region of straight, parallel, equidistant isobars resulting from a distribution of temperature decreasing uniformly upward and northward in accordance again, roughly, with what is often observed. The latter pressure system, called the "stationary system," results in a geostrophic wind increasing upward, from zero at the surface, to great velocities at the cirrus level.

The fundamental differential equations of motion, which include the effects of turbulence and ground resistance, to which this scheme leads, can not be integrated; and the author develops a graphical method of solution, by which synchronous representations of air trajectories relative to the ground, trajectories relative to the moving center of the cyclone, and wind velocities relative to the ground, may be constructed for any level. From these, the regions of rising and falling air may be found also. The supply of energy necessary for the maintenance of a travelling wind system is assumed to come from the kinetic energy of the upper layers of the current produced by the stationary pressure system.

The cyclone, on this theory, may be divided into four principal or representative strata:

(1) The Ground Stratum, in which there is little or no wind arising from the stationary system; in this stratum, the actual wind velocities as depicted on a synoptic chart give the impression that the air is streaming from every side toward the center, but in reality the air streams into the cyclone only at the front; most of it leaves at the rear, but a minor part is drawn toward the center and must there ascend. Over most of the interior of the cyclone, air is rising; and in the outer parts and outside the cyclone proper, air is falling.

(2) The Lower Stratum of the free atmosphere, comprising that region in which the velocity of the wind due to the stationary system is *less* than the speed of the cyclone; in this stratum, a considerable part of the air spirals very slowly toward the center.

(3) The Central Part of the cyclone, in which the wind due to the stationary system has the *same* velocity as the speed of travel of the cyclone. Relative to the moving center, the air moves round and round this center in concentric circles. No addition to ascending or descending air is contributed by this stratum.

(4) The Higher Stratum of the free atmosphere, in which the wind due to the stationary system *exceeds* in velocity the speed of the cyclone; the air which is thrust up in the lower levels of the cyclone can not escape until it reaches this highest stratum, where it is carried forward out of the system. The descending air is similarly sucked from the highest stratum to the ground. The author considers that in most cases the decay of an Atlantic storm is due to the dying out or disturbance of the stationary pressure field.

An inversion of temperature will occur in the free air only where air is warmed up when contracted during descent, and, since this air is coming from the upper layers, it will be dry. However, a discontinuity of temperature, or "cold front" will be formed in the lowest level, at the place where observation shows the squall-line to exist; but the surfaces of discontinuity will vanish in the free air: The polar front is thus a consequence of the manner in which the air motions take place, and is not, as in Bjerknes' theories, the cause of the cyclone.

The theory is claimed to provide a foundation for an adequate explanation of extratropical cyclones; and the author is satisfied that it is in reasonable accord with observed facts. A number of facts which are explained by the theory are pointed out; and a critical examination of the foundations and postulates of the theory leaves a favorable impression. Of course, a *complete* theory must take into account many factors necessarily neglected in this study.

The kinematical problem with which Ryd has concerned himself is quite similar to the one recently investigated by Kobayasi, and the conclusions of the two are substantially in agreement.[3]

ON THE MECHANISM OF CYCLONES AND ANTICYCLONES.

By T. KOBAYASI.

[Abstracted from *the Quarterly Journal of the Royal Meteorological Society*, July, 1923, pp. 177-189.]

Contrary to the Bjerknes conception of the function of the polar front as a causative factor in the formation of cyclones and anticyclones, the author begins by regarding the cyclone as a circular phenomenon. This suggestion arises from the widely observed fact that not all cyclones have a well-defined polar front, especially those that are slow moving.

Therefore, regarding the cyclone kinematically, the author deduces mathematically the equations of air trajectories over the earth's surface. To accomplish this, certain assumptions are necessary: (1) In the central region of a cyclone, called by the author the "principal part," there is not great variation of wind speed with increase of distance from the center; (2) outside the "principal part" the air is moving horizontally; (3) in the "principal part," at the surface, the wind is moving relative to the center approximately three times as fast as the center is advancing, and at an angle of 20° to the isobars. The resultant air trajectories thus theoreticalld obtained agree fairly well with those found by Shaw any Lempfert in their study of the "Life history of surface air currents." In the treatment of more complicated conditions the determination of theoretical air trajectories must be graphical but the results will not differ much from those found in this study, providing it is always assumed that within the storm the air is moving faster than the velocity of translation of the center and that at a distance from the center the air is moving slower than the velocity of translation.

The important feature thus revealed is that, along a line extending from the center of the cyclone toward the southwest there will occur a sharp discontinuity of temperature *if there is a steep horizontal gradient of temperature normal to the direction of translation of the cyclone.* If there is no such temperature gradient in the field of the storm's activity, this thermal discontinuity will not appear. This line corresponds to the well-known Bjerknes "cold front." The author maintains, it is seen, that the thermal discontinuity is a *result* and not a *cause* of the cyclone.

The angle between the actual wind and the gradient decreases with increase of altitude, and the ratio of wind velocity to velocity of translation of the pressure system also increases. At a certain height, assumed by the author to be 1,000 meters, the angle becomes 0° and this

[3] See this REVIEW, pp. 37-38.

ratio about 5.3. The result of this decrease of angle and increase of ratio is that the line of discontinuity in the free-air overruns that at the surface, producing instability, if there be great contrast of temperature, the heavier air from above descending to the surface and causing the cold front to advance faster than the storm center.

Another line of importance comes from the mathematical treatment, and that is called by the author "the boundary of the centripetal current," a curve which approaches the storm center from the southeast, crosses the cold front at a point south of, and where no motion exists relative to, the storm center, passes around the storm center to the north, and finally off again to the southeast approximately parallel to, but some distance north of, its incoming branch. Within the area determined by this line, all the air reaches the storm center and ascends; outside the line, the air moves so as to flow away to the rear of the cyclone (relative to the storm center). The width of this belt of inflowing air is at a maximum about 150 meters above the ground, and it disappears at the level where the actual wind agrees in direction with the gradient wind. The conclusion is that the storm thus removes the air within this narrow belt extending toward the southeast, and brings the air on either side of it in contact, thus making such difference of temperature as may exist manifest itself most strongly along the cold front, or squall line.

As to the steering line, or warm front, the author is not prepared to offer an explanation, but the fact that it does not always occur causes him to suggest that this line is not essential to the cyclone, but that it is a thermal discontinuity left behind by a preceding cyclone and adopted by the storm in question. This would preclude the first storm in the Bjerknesian "family" ever having a warm front.

Slight attention is given the anticyclone owing to the difficulties of making appropriate assumptions. He shows that temperature discontinuities may be produced by an anticyclone, but the temperature differences will be usually very small.—*C. L. M.*

THE TWO-AND-A-HALF YEAR CYCLE IN WEATHER AND SOLAR PHENOMENA.

H. W. CLOUGH, Meteorologist.

[Author's Abstract.[1]]

During the last 25 years a number of writers have called attention to a short cycle in weather elements, and estimates of its mean length have varied from 2.5 to 3.7 years. Bigelow (1894) was probably the first to mention this cycle which he regarded as one-fourth of the sunspot cycle, or 2¾ years, but subsequently referred to it as a 3-year cycle. Later investigators include Lockyer (1902–1908), Arctowski (1909), Braak (1910), Wallén (1910), Johannson (1912), Krogness (1917), and Helland-Hansen and Nansen (1917). Those who regarded the length of the cycle as 3 to 3.7 years employed annual means, thus obscuring some short fluctuations of small amplitude, while those who made the length 2.5 to 3 years, as Arctowski, Wallén and Helland-Hansen and Nansen employed consecutive 12-month means.

In the present investigation the author has employed the two 12-month means centering January 1 and July 1, the latter being the ordinary calender-year mean. The annual variation is eliminated, while the large departures of the colder months are grouped together in the January 1 mean. A plot of these two yearly means satisfactorily exhibits the short cycle, although in some cases the existence of a maximum or minimum phase is indicated only by an inflexion in a continuous ascent or descent of the curve, due to a longer variation. The amplitude of the short cycle is, generally, however, sufficiently large in comparison with that of the variations of longer period, as the 7 or 11 or 35 year cycles, so that the determination of the maximum and minimum phases is, as a rule, quite unaffected by the existence of the longer cycles.

The object of the investigation has been to determine, to the nearest quarter-year the maximum and minimum phases of the cycle as far back as temperature records are available—1770 in the United States and 1730 in Europe. Pressure records from 1740 in Europe have also been examined and serve to confirm the epochs derived from the temperature curves. Rainfall curves exhibit the cycle with much less regularity than temperature and pressure. Contemporaneous curves for several stations have been examined during the entire period of time for mutual confirmation and elimination of instrumental errors, change of exposure, or location and the small differences normally occurring between localities more or less distant from each other. The United States records from 1770 to 1923 yield a mean interval of 2.30 years between successive maxima and minima of the cycle. The mean deviation of the intervals from this mean is 0.35 year, while the mean variability is 0.34 year. The latter measure of dispersion being even smaller than the mean deviation, while normally it should be 1.4 ($\sqrt{2}$) times greater, indicates the existence of marked secular variations in the length of the cycle. A plot of the phase intervals from 1770 shows a highly irregular variation about the mean interval,. 2.30, ranging from 2 years or less about 1775, 1815, 1850, 1880, and 1910, or the epochs of maximum rainfall in the Brückner cycle, to 2¾ or more years at the intermediate dates. There is also a marked tendency to a shortening of the cycle within a few years after each sunspot maximum in the 11-year cycle. The range of this 11-year variation is about one-half that of the 35-year variation. The mean duration of the cycle from European data beginning 1728 is 2.20 years. This lower average is due to the low average, 2 years, of the period 1728–1770. There is furthermore apparent from the plot a progressive increase in the length of the cycle from the middle of the eighteenth century to the present time, which is, in all probability, due to a long cycle of about 300 years. A point to be emphasized is that the cycle changes in length gradually, not abruptly. The epochs of high and low temperature in Europe and the United States, east of the Rocky Mountains, are, on the average, practically coincident, Europe averaging 0.06 year later. The individual differences from true coincidence average about six months, and 85 per cent of these differences are between ± 0.75 year.

From inspection of the curves of temperature it is apparent that the amplitude at the above-mentioned epochs of maximum rainfall in the Brückner cycle is perhaps only one-half the amplitude at the opposite epochs, 1800, 1830, 1865, 1890, and 1925. At Portland, Oreg., the length of the variation was about 2.20 years and the mean amplitude 1.5° in 1880 and 1910, while in 1890 and 1920 the values were 3 years and 3°, re-

[1] The complete article, of which this is an abstract, will appear in a later number of the REVIEW.

spectively. Regarding the relations between pressure and temperature it is found that over southwestern Europe the epochs of low pressure slightly precede, about 0.3 year, the epochs of low temperature over the United States and Europe, while on the other hand, at the same time the pressure is high over western North America. Correlation between the pressure in Spain and the pressure at St. Paul, Minn., during the period 1875–1918 gives −0.41, while with the temperature at St. Paul the correlation is +0.65. There is also apparent a lag, or time interval, between regions differing in longitude and latitude. For example, the epochs at Portland precede those at Toronto by about 0.75 year, and St. Paul precedes New Orleans by about 0.35 year.

Bigelow and Lockyer employed solar prominence data to show solar relations with terrestrial weather. The prominence data are, however, inadequate, owing to the necessary limitation of the observations to the solar limb. I have employed, therefore, the Greenwich measurements, half-yearly means, of the mean heliographic latitude of the entire spotted area since 1875. When an 11-year variation is eliminated and minor fluctuations smoothed out, there is disclosed a well-defined cycle, averaging 2¼ years, during which period the excess of spots shifts from one hemisphere to the other and back again. When a curve of these solar variations in latitude is compared with a curve of temperature, as for example, St. Paul, it is apparent that each epoch of low temperature is preceded by a corresponding epoch of spot excess in the Northern Hemisphere, the average interval of time intervening being about 1.25 years. This time interval varies with the Brückner cycle, being about three-fourth year in 1880 and 1915 and 1¾ years in 1895. Correlating the solar and temperature data for the period 1875–1923 for simultaneous values and also for successive lags in the temperature data varying by half-yearly intervals, the following results are obtained. For simultaneous values the result is set opposite zero in the tabulation below; shifting the temperature curve to the left in successive half-year intervals the results are as shown. Values for the solar Northern Hemisphere are called +.

0	+0.40	6	−0.63
1	−.51	7	+.15
2	−.56	8	+.60
3	+.26	9	+.31
4	+.60	10	−.50
5	+.15	11	−.31

This table shows that the phases of the two curves come into approximate conjunction and opposition with each other as the temperature curve is successively shifted to the left, on an average of about every 2¼ years, since the maximum correlation coefficients of like sign occur about 4½ half-yearly intervals apart.

Wolfer's smoothed sunspot numbers since 1750 when plotted, and the primary 11-year variation graphically drawn thereon to smooth out the minor fluctuations, disclose secondary maxima averaging 2¼ years apart, with epochs corresponding to terrestrial temperature epochs at definite average time intervals therefrom. While owing to the nature of the early sunspot observations these epochs are not quite as satisfactory as the epochs since 1875, there is sufficient evidence to indicate that the cycle has persisted since 1750, and that its length has varied synchronously with that of the meteorological cycle.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS.

By HERBERT H. KIMBALL, in Charge, Solar Radiation Investigations.

INSTRUMENTS AND EXPOSURES.

The measurements of direct solar radiation summarized in Table 1 are made with a Marvin pyrheliometer, which is described in the REVIEW for November, 1919, **47**: 769. The measurements of the solar and sky radiation received on a horizontal surface summarized in Table 2 are obtained at Madison, Wis., and Lincoln, Nebr., by means of a Callendar recording pyrheliometer, which is described in the REVIEW for August, 1914, **42**:474. At Washington, D. C., and Chicago, Ill., they are obtained by means of a thermoelectric recording pyrheliometer, which is described in the REVIEW for May, 1923, **51**: 239–242.

A description of the exposures of the Marvin pyrheliometers, and the method of obtaining solar radiation intensities at the desired zenith distances of the sun, is given in the REVIEW for January, 1916, **44**: 2. The Callendar pyrheliometers at Lincoln and Madison are exposed as described in the REVIEW for April, 1916, **44**:179 and 180, respectively, except that at Madison the dome and flagstaff on University Hall no longer shade the pyrheliometer at certain times as formerly. Callendar receiver No. 9864 is still in use at Madison, but the receiver at Lincoln was replaced by No. 13129, formerly in use at Washington, on November 7, 1922. Thermoelectric pyrheliometer No. 5, in use at Washington, is exposed on the capstone of a ventilating flue of the College of History Building, American University, at a height of 451 feet, or 137 meters, above sea level, which is the exposure formerly given the Callendar pyrheliometer. A description of the exposure of thermoelectric pyrheliometer No. 6 at the Weather Bureau Observatory, Chicago University, is given in the REVIEW for October, 1923, **51**: 533–534.

In the REVIEW for January, 1916, **44**:3, is given a description of the exposure of the Pickering polarimeter employed at Washington for measuring skylight polarization, and also an account of the manner in which the measurements are made. The exposure of a similar instrument in use at Madison is described in the REVIEW for January, 1917, **45**:2.

MEASUREMENTS DURING JANUARY, 1924.

From Table 1 it will be seen that solar radiation intensities were generally below normal at Washington and above normal at Lincoln. At Madison but few measurements were obtained during the month on account of poor sky conditions.

Table 2 shows an excess in the total radiation received on a horizontal surface, most pronounced at Lincoln, least pronounced at Madison.

Skylight polarization measurements obtained at Washington on 11 days give a mean of 56 per cent with a maximum of 67 per cent on the 11th. The latter is close to the average maximum for January, but 56 per cent is below the January average. At Madison the ground was covered with snow throughout the month which explains the low polarization value of 51 per cent obtained on the 3d.

TABLE 1.—*Solar radiation intensities during January, 1924.*

[Gram-calories per minute per square centimeter of normal surface.]

Date.	75th mer. time.	Sun's zenith distance.									Local mean solar time.
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
		Air mass.									
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
Washington, D. C.											
1924.	*mm.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Jan. 4	2.36	0.57	0.71	0.85							2.36
7	2.06				1.31			1.02	0.86	0.77	1.37
8	2.49	0.76	0.88	1.01	1.16			1.04	0.85	0.74	3.15
9	4.37	0.69	0.81	0.99	1.22	1.47		0.97	0.82	0.69	3.45
11	13.61					1.61	1.35	1.12	0.95	0.81	7.29
12	3.45	0.70	0.81	1.00	1.16			0.94	0.78	0.62	3.30
14	2.16	0.49	0.64	0.79			1.02	0.78	0.64	0.48	2.26
15	2.49				1.13						3.15
17	3.99	0.56	0.68	0.82							3.63
18	3.63		0.44	0.57							3.63
21	0.64	0.85	0.89	1.12			1.16	0.96	0.78	0.63	0.46
23	2.06				1.25		1.26				1.96
25	4.95						1.29				6.02
26	0.96	0.88	0.99	1.21	1.39	1.59	1.39	1.09	0.92		1.24
28	1.78	0.39	0.43	0.62	1.04						2.16
Means		0.65	0.73	0.90	1.21		1.24	0.99	0.82	0.67	
Departures		−0.09	−0.11	−0.09	−0.02		+0.02	−0.03	−0.04	−0.11	
Madison, Wis.											
Jan. 3	0.66			1.24							0.79
21	0.25			1.20							0.28
25	0.86							1.27			0.58
Means				(1.22)				(1.27)			
Departures				−0.02				+0.03			
Lincoln, Nebr.											
Jan. 2	1.52					1.49	1.33	1.18	0.93		1.60
4	0.74	1.07	1.18	1.34	1.52	1.73					0.79
5	0.36							1.19	1.03		0.64
12	1.07		1.20	1.33	1.48			1.23	1.04	0.76	1.24
16	0.56			1.30	1.47						1.19
17	0.79	0.93	1.08	1.25	1.46						2.36
19	1.19							1.32	1.11	1.03	0.96
23	3.00						1.28	1.11	0.95	0.73	3.45
29	3.45				1.38		1.40				4.57
Means		(1.00)	1.15	1.30	1.46		1.34	1.21	1.01	0.84	
Departures		+0.08	+0.12	+0.13	+0.09		+0.08	+0.02	−0.03	−0.07	

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.				Average daily departure for the week.			Excess or deficiency since first of year.		
	Chicago.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
1924.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	106	139	160	220	−14	+19	+30	− 96	+130	+213
8	84	190	126	178	+31	−27	−20	+121	− 57	+ 70
15	96	142	188	261	−26	+21	+51	− 62	+ 93	+427
22	115	228	194	231	+50	+ 9	+ 3	+286	+153	+445

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month varied considerably, as compared with the normal, at a number of land stations on the coast and islands of the North Atlantic. In the following table the average sea-level pressure is for 8 a. m., 75th meridian time, while the departures are only approximate, as the normals were taken from the Pilot Chart, and are based on Greenwich mean noon observations, or 7 a. m., 75th meridian time.

Station.	Average pressure.	Departure.
	Inches.	Inches.
St. Johns, Newfoundland	29.84	-0.06
Nantucket	30.11	+0.01
Hatteras	30.23	+0.10
Key West	30.11	+0.01
New Orleans	30.24	+0.13
Swan Island	29.95	-0.03
Turks Island	30.15	+0.10
Bermuda	30.29	+0.15
Horta, Azores	30.10	+0.04
Lerwick, Shetland Islands	29.78	+0.08
Valencia, Ireland	29.78	-0.12
London	29.97	-0.03

January is ordinarily the stormiest month of the year over the North Atlantic; taking the ocean as a whole, the number of days with winds of gale force during the month under discussion greatly exceeded the normal as shown on the Pilot Chart, and January, 1924, will be long remembered in maritime circles, on account of the large number of unusually severe gales. There was not a day during the month when heavy winds were not reported from some section of the ocean, and not only were the steamer lanes swept by cyclonic disturbances in quick succession, but on a number of days the storm area extended as far south as the Azores or Bermudas, while two exceptionally severe "northers" were reported from the Gulf of Mexico.

Over the greater part of the ocean the number of days with fog was apparently somewhat below normal, although it was observed on from 7 to 9 days over the Grand Banks and on 3 days in the Gulf of Mexico. It was comparatively rare over the steamer lanes.

On the 1st Father Point, Quebec, was near the center of a LOW that moved rapidly eastward, and on the 3d was central near latitude 52° N., longitude 38° W. On the 2d and 3d heavy winds prevailed over the greater part of the ocean, north of the 40th parallel, and on the 2d moderate gales were also reported from the vicinity of the Bermudas. Storm log:

British S. S. *Varentia:*

Gale began on the 1st, wind SW. Lowest barometer 29.70 inches at noon on the 2d, wind SW., 12, in latitude 47° N., longitude 38° 50′ W. End on the 2d, wind NW. Highest force of wind 12, SW.; shifts SW.-NW.

On the 4th Newfoundland was covered by a LOW that moved rapidly eastward, and was responsible for one of the most severe disturbances of the month. Charts VIII to XI cover the period from the 5th to 8th, inclusive, and an examination of these charts will give an idea of the unusual conditions that prevailed over the ocean and also show the "norther" of the 5th and 6th in the Gulf of Mexico. Storm logs:

Dutch S. S. *Boschdijk:*

Gale began on the 4th, wind SW. Lowest barometer 29.18 inches. At 10 a. m. on the 4th wind W., 9, in latitude 47° 43′ N., longitude 36° 48′ W. End on the 6th, wind NW. Highest force of wind 10 WNW.; shifts not given.

American S. S. *East Side:*

Gale began on the 6th, wind W. 7. Lowest barometer 29.58 inches at 3 a. m. on the 6th, wind W. 7, in latitude 41° 10′ N., longitude 66° 20′ W. End at 7 p. m. on the 6th, wind N. Highest force of wind 11, W.; shifts E.-SE.-WSW.-W.

American S. S. *Schenectady:*

Gale began on the 7th, wind SW. Lowest barometer 28.28 inches at midnight on the 7th, wind SW. 6, in latitude 51° N., longitude 19° W. End on the 8th, wind WSW. Highest force of wind 12, NW.; shifts SW.-W.-NW.

Honduran S. S. *Yoro:*

Gale began on the 5th, wind NNW. Lowest barometer 30.17 inches at 5:30 a. m. on the 5th, wind NNW., in latitude 21° 06′ N., longitude 94° 50′ W. End on the 6th, wind N. Highest force of wind 10; shifts NW.-NNW.

From the 8th to the 12th an area of low pressure remained nearly stationary off the coast of Great Britain, causing turbulent conditions over a large part of the middle and eastern sections of the ocean. On the 12th storm logs were received from vessels in the vicinity of the Azores and Madeira, as well as from the region between the 60th meridian and American coast.

Storm log.

French S. S. *La Bourdonnais:*

Gale began on the 9th, wind W. Lowest barometer 29.14 inches at 7 p. m. on the 9th, wind W., in latitude 47° 40′ N., longitude 31° 41′ W. End on the 12th, wind N. Highest force of wind 12, W.; shifts W.-NW.-N.

From the 13th to 15th an area of low pressure covered the middle and eastern sections of the steamer lanes, attended by gales of hurricane force, while on the 15th there was a second LOW in the vicinity of Newfoundland, the two storm areas nearly meeting in mid-ocean, leaving only a narrow belt of comparatively moderate winds between the 35th and 40th meridians. Storm logs:

French S. S. *La Bourdonnais:*

Gale began on the 13th, wind W. Lowest barometer 29.37 inches at 4 p. m. on the 13th, wind W., in latitude 46° 20′ N., longitude 38° 45′ W. End on the 15th, wind WNW. Highest force of wind 12, W.; shifts W.-WNW.

British S. S. *Steadfast:*

Gale began on the 12th, wind SW. 7. Lowest barometer 29.25 inches at 8 p. m. on the 14th, wind NW. 11, in latitude 48° 20′ N., longitude 32° 15′ W. End on the 15th, wind NNW. Highest force of wind 11, NW.; shifts SW.-W.-NW.

On the 16th the western LOW was central near latitude 47° N., longitude 35° W., and continuing in its easterly movement reached the British coast on the 19th. On the 18th Newfoundland was again surrounded by a moderate depression which gained in intensity as it moved northeastward. On the 17th and 18th vessels in the region between the 25th and 35th parallels and 35th and 50th meridians reported northerly winds, force 7-9, with barometric readings ranging from 29.90 to 30.10 inches.

From the 19th to the 25th there was apparently an area of low pressure over mid-ocean, central north of the 45th parallel, the storm area expanding and contracting from day to day, reaching as far south as the 30th parallel on the 20th. Storm logs:

British S. S. *Slavic Prince:*

Gale began on the 15th, wind SSW. Lowest barometer 29.25 inches at 6 a. m. on the 16th, wind NW. 12, in latitude 43° 14′ N., longitude 44° 45′ W. End on the 17th, wind N. Highest force of wind 12, NNW.; shifts NW.-NNW.-N.

American S. S. *West Campgaw:*

Gale began on the 19th, wind WNW. Lowest barometer 29.29 inches at 6 a. m. on the 19th, wind NW. 10, in latitude 46° 35′ N., longitude 40° 10′ W. End on the 20th, wind W. Highest force of wind 10; steady NW.

Dutch S. S. *Nickerie:*

Gale began on the 19th, wind S. Lowest barometer 29.74 inches at 7 a. m. on the 20th, wind SSE., in latitude 29° 11′ N., longitude 23° W. End on the 20th, wind SW. Highest force of wind 9, S.; shifts S.-SSE.

On the 20th and 21st the second severe "norther" of the month occurred in the Gulf of Mexico; this reached its greatest intensity on the 21st, and the daily weather map for that date shows a barometric reading of 30.58 inches at Galveston and 29.92 inches at Swan Island. While the gradient between these two stations was not as steep as on the 6th, the force of the wind was apparently as high. The Greenwich mean noon observations from a number of vessels give northerly winds, force 7–9, with barometric readings ranging from 30.14 to 30.44 inches.

Storm log:

American S. S. *Pennsylvania:*

Gale began on the 20th, wind NE. Lowest barometer 30.01 inches at 6 a. m. on the 20th, wind NE. 8, in latitude 23° 35′ N., longitude 88° 20′ W. End on the 22d, wind N. Highest force of wind 9, N.; shifts NE.-N.

On the 25th New York was near the center of a disturbance that moved northeastward, and on the 27th was central in the vicinity of St. Johns, Newfoundland; during this period gales were reported by vessels west of the 50th meridian, as shown by following storm log:

American S. S. *Lightburn:*

Gale began on the 25th, wind SW. Lowest barometer 29.45 inches at 7 a. m. on the 25th, wind SSW. 10, in latitude 39° 38′ N., longitude 69° 54′ W. End on the 27th, wind NW. Highest force of wind 10, SSW.; shifts 6 points.

On the 25th and 26th there was a shallow depression near latitude 35° N., longitude 35° W., with gales in the westerly quadrants. Storm log:

British S. S. *Bloomfield:*

Gale began on the 24th, wind ESE. Lowest barometer 29.86 inches at 2 p. m. on the 25th, wind W., in latitude 36° 10′ N., longitude 36° 42′ W. End on the 26th, wind NNW. Highest force of wind 9, NW.; shifts WNW.-NW.-NNW.

On the 29th and 30th an area of low pressure was evidently central somewhere in the vicinity of Iceland, although it was impossible to locate it accurately on account of lack of observations. On the 29th westerly to southerly gales swept the steamer lanes east of the 50th meridian, while by the 30th the storm area had contracted considerably.

On the 31st Bermuda was about 10° west of the center of a LOW, and vessels between the 45th and 60th meridians reported unusually heavy winds.

Storm log:

British S. S. *Caldy Light:*

Gale began on the 30th, wind SE. Lowest barometer 29.60 inches at 3 p. m. on the 31st, wind SE. 10, in latitude 36° 04′ N., longitude 51° 05′ W. End on February 1, wind NW. Highest force of wind 10, SE.; shifts SSE.-S.-SW.

SOUTH ATLANTIC OCEAN.

By ALBERT J. MCCURDY, Jr.

Weather reports received from vessels that were in the South Atlantic Ocean in January, 1924, indicate that stormy conditions prevailed off the coast of Brazil in the first and middle decades of the month.

The Dutch S. S. *Poeldijk*, Captain Yaski, proceeding from Rotterdam to Buenos Aires, encountered on January 8, while off the southern coast of Brazil, fresh to strong gales with overcast weather and rough seas. Mr. P. Smit, observer, states that the lowest pressure observed was 756 mm. (29.76 inches), this occurring at 4 p. m. in 26° 40′ S., 47° 41′ W. The wind at the time was SSW., force 8, increasing at 1 p. m. to force 9, followed by a heavy rain shower. Gale ended on the 9th, wind SW.

On the same date the American S. S. *F. Q. Barstow*, Capt. H. Wallace, New York toward Buenos Aires, experienced a moderate gale with rough seas in 35° S., 54° 30′ W. Observer H. C. Strong reports that the lowest pressure, 29.97 inches (corrected), was observed at 8:24 a. m., at which time the wind was SSW., force 7.

On January 9 a fresh gale was encountered by the Dutch S. S. *Bellatrix*, Capt. C. Spuy, Cardiff toward Buenos Aires. Second Officer A. Barendrecht reports that at 9:15 a. m., while in 22° 45′ S., 41° 15′ W., the barometric reading was 29.76 inches (corrected); wind S., force 5, increasing to a fresh gale after sunset. The lowest pressure observed was 29.47 inches (corrected). This occurred at 10 p. m. and was followed by a heavy thunderstorm. The weather cleared on the morning of the 10th.

On the 15th the American S. S. *Kenowis*, Capt. E. A. Schaefer, proceeding from Port Arthur to Montevideo, experienced winds of gale force off the southern coast of Brazil. Second Officer William McFaull reports rough northeast seas with overcast and squally weather. The lowest pressure, 29.81 inches (corrected), was observed at 8:43 a. m. 29° 20′ S., 49° 10′ W. The wind at this time was NE., force 7.

NORTH PACIFIC OCEAN.

By WILLIS E. HURD.

The weather over the North Pacific Ocean during January, 1924, exhibited wide extremes of intensity, as noticed by mariners during entire transoceanic voyages. On the one hand, Mr. C. H. Moen, observer and fourth officer on board the American S. S. *President Jefferson*, Capt. F. R. Nichols, Seattle to Yokohama from the 23d to the 31st of the month, has the following to remark:

This has been a most remarkable voyage. We made the run in 10 days and 5 hours, arriving in Yokohama over 12 hours ahead of schedule. It is rare to find no storm, no fog, and smooth seas for this time of the year. A few snow squalls were encountered, but they never lasted more than a few minutes at the most.

On the other hand is the record of strong gales to hurricane winds, and the violent seas which caused more than one stout vessel to heave to for hours at a time, awaiting an abatement of the storm.

The pressure system showed the Aleutian LOW to be existent throughout the month, although fluctuating considerably in area and intensity. The eastern North Pacific HIGH seems to have been less well developed than usual, and persisted on few consecutive days. Two storms from low latitudes entered the area between Hawaii and California, and southward extensions of the Aleutian cyclone occupied much of the usual high pressure region during most of the last decade. However, at the close of the month the HIGH was becoming well established along the 30th parallel to the eastward of the 160th meridian of west longitude. A strong anticyclone overlay northern Alaska from the 20th to the 25th.

In east longitudes high pressure prevailed over the China coast, and the northeast monsoon seems to have been active. No reports of typhoons are at hand. Greater storm activity, however, occurred in east than in west longitudes during January, and moderate to dangerous gales were of frequent occurrence over the

middle and northern steamship routes of the western Pacific between the 25th and 50th parallels.

The mean monthly pressure at Dutch Harbor, which is generally regarded as indicating the intensity of the Aleutian LOW, was 29.50 inches, as compared with the average January pressure of 29.71. This comparison is based on p. m. observations. On the same basis, pressure in the Aleutian area has not exceeded the average since February, 1923, a period of 11 months. In the present January pressure was continuously low from the 1st to the 13th and from the 23d to the 30th. The highest reading, 30.10, was recorded on the 21st; the lowest, 28.76, on the 13th. Absolute range, 1.34 inch. At Honolulu conditions were about the reverse of those at Dutch Harbor. Pressure was high from the 1st to the 10th and after the 23d; low during the intermediate period. The average of p. m. observations was 30.04, or 0.03 inch above normal. The highest reading, 30.19, was recorded on the 28th; the lowest, 29.80, on the 18th. Pressure at Midway Island was without marked features, averaging normal, or 30 inches (29 days). The highest, reading, 30.20, was recorded on the 4th; the lowest, 29.80, on the 25th.

At Honolulu quiet conditions prevailed, although a few high-pressure gales occurred during the early part of the month, particularly on the 6th, when a maximum velocity of 46 miles an hour from the east was registered. There was less cloudiness than during any other month since the record began in 1904, and three-fourths of the daylight hours were sunny. Only 0.12 inch of rainfall occurred—this being the least of any month since the beginning of precipitation records in 1877.

Storm conditions over the ocean began with a hurricane wind on the 1st and ended with a whole gale on the 31st, with 15 intermediate days on which seamens' reports show forces of 11 to 12.

The British S. S. *Canadian Transporter*, eastward bound, after weathering a hurricane on December 27, encountered another on January 1, in latitude 48° 10′ N., longitude 177° 40′ W., lowest pressure 28.88 inches. Gales as high in force as 10 were observed by other vessels on this date between 40° and 50° N., 160° W. and 160° E.

On the 2d and 3d the American S. S. *President McKinley*, westward bound, passed through the same cyclone, experiencing the highest wind, force 11 from the west by south, and noting the lowest pressure, 28.81 inches, in latitude 52° 25′ N., longitude 167° 45′ W.

On the 3d and 4th this widespread storm seems to have attained its maximum energy. The center at this time was to the westward of that of the two earlier days, being near 47° N., 170° E.

The Panaman S. S. *Ida* during the first eight days of the month had a tempestuous voyage from the Orient toward British Columbia. On the 1st, in 45° 23′ N., 162° E., she was in a west-northwesterly gale, force 10, pressure 29 inches. The rough seas and intermittent gales continued through the 2d. On the 3d she encountered hurricane winds, with pressures generally below 29, the minimum being 28.74. On the 4th the vessel proceeded in hurricane winds for about half the day, accompanied by heavy rain and snow squalls, her position now being near 47° 28′ N., 173° E. On the 5th the gales continued until she crossed the 180th meridian. Early on the 6th there was a lull, during which time pressure fell rapidly. On the morning of the 7th a whole gale from the east-northeast was blowing, and at noon, in 48° 03′ N., 169° 33′ W., the pressure had fallen to 28.24 inches, the lowest recorded for the North Pacific during the month.

While most of the northern part of the ocean was disturbed by the Aleutian cyclone, low pressure developed on the 3d near 40° N., 140° W., and caused gales of forces 8 and 9 along the United States-Honolulu routes. This disturbance disappeared to the northward on the 4th.

On the 7th, while the deepest cyclone of the month was prevailing to the southward of Dutch Harbor, a storm which gave a west wind of force 9 at Nemuro was crossing northern Japan. It caused some gales at sea, but was followed on the 10th by a more widespread disturbance which affected much of the ocean from the east coast of Japan to the Aleutian area, and north and south from the 30th to the 50th parallels, giving whole gales to storm winds on the 10th, 11th, and 12th.

Many vessels were involved in the turbulent conditions of this period. Those reporting winds of force 11 were the American steamships *Anna E. Morse* and the *Memphis City*. The *Anna E. Morse*, westward bound, experienced the worst of the gale from the northwest on the 10th and 11th near 46° N., 170° to 174° E., lowest pressure 28.68, on the 12th. The *Memphis City*, steaming westward along the southern edge of the cyclone, in latitude 30° 40′ N., longitude 168° 20′ E., with lowest pressure at 29.71 inches, nevertheless encountered a west-northwesterly gale, force 11, with seas so tremendous that she hove-to and used oil to calm the waves.

The next stormy period was that of the 15th and 16th. Although scattered gales of moderate force occurred along the California and northern Japanese coasts, and in isolated regions elsewhere, the main energy of the winds appeared over middle longitudes from the Alaskan Peninsula southwestward, as indicated. The highest wind force recorded was 11, noted on the 15th by the following vessels: The American S. S. *West Cayote*, wind southwest, lowest pressure 29.55, in 52° 12′ N., 164° W.; the American S. S. *West Islip*, wind northwest, lowest pressure 29.16, in 35° 34′ N., 178° W.; and the Norwegian S. S. *Eriken*, wind northwest, lowest pressure 29.58 (uncorrected), in 34° 41′ N., 173° 09′ E. On the 16th the American S. S. *Anna E. Morse* encountered a northwesterly gale, force 11, lowest pressure 29.19, in 41° 18′ N., 154° 16′ E.

On the 15th and 16th a depression appeared slightly to the eastward of Hawaii, and on the 18th gave Honolulu the lowest pressure of the month. It possessed no great energy, although gales of force 8 were noted on the 20th and 22d by vessels within latitudes 27° to 40° N., longitudes 145° to 160° W. The LOW seems finally to have pursued a north-northwesterly course and mingled with the Aleutian disturbance to the southeastward of Dutch Harbor on the 23d.

During the last decade of the month stormy weather as a rule was of insufficient violence to greatly disturb vessels plying the waters to the eastward of the 170th meridian of west longitude. Only one vessel in this area reported a wind force exceeding 9. This was the Japanese S. S. *Hayo Maru* which, enroute toward Coos Bay, fell in with a south-southeast hurricane, lowest pressure 29.48, on the 26th, in 44° 05′ N., 129° 55′ W. The center of this storm lay over the southern portion of the Gulf of Alaska, whence it had drifted from the central Aleutians. An offshoot entered the British Columbian coast on the 26th–27th.

To the westward of 170° W. much violent weather occurred during the 21st to 31st. On the 21st the American S. S. *West Niger*, while in 37° 47′ N., 161° 25′ E., encountered westerly squalls of hurricane force, lowest pressure 29.16 inches. On the 22d the British S. S. *Tascalusa*, in 36° 50′ N., 152° 50′ E., met frequent

hurricane squalls, with wind blowing constantly from the northwest. On these two days gales of force 10 to 12 covered the area between 150° and 170° E., 30° and 50° N.

On the succeeding days of the month storm to hurricane winds were reported as follows: On the 24th, by the American S. S. *West Niger*, NW. 11, lowest pressure 29.35 inches, in 36° 41′ N., 152° 33′ E.; on the 25th, by the Japanese S. S. *Manila Maru*, NE. 11, lowest pressure 29.39, in 44° 19′ N., 159° 34′ E.; on the 27th, by the American S. S. *West Chopaka*, NW. 11, lowest pressure 29.35, in 37° 19′ N., 148° 04′ E.; on the 31st, by the American S. S. *Dilworth*, SE. to WSW. 11, lowest pressure 28.88, in 34° 58′ N., 156° 16′ E.

From the two foregoing paragraphs, it will be seen by how narrow a margin of escape from preceding and subsequent rough weather did the *President Jefferson*, previously mentioned, day by day make her remarkable, storm-free voyage.

Attention must be directed to the area lying along the canal route between the 85th and the 100th meridians. Unusual storm conditions prevailed from the 5th to the 9th throughout this region, the winds becoming especially violent on the 6th and 7th over the Gulf of Tehuantepec. The American S. S. *Steel Scientist*, southward bound, commented as follows:

> January 5. Encountered a wind from NNE. in latitude 14° 56′ N., longitude 96° 32′ W., barometer 29.91. Constant blow from NNE., reaching up to force 11, lowest barometer 29.81 on the 6th, in 14° 44′ N., 96° 06′ W. Ended Jan. 7 in latitude 13° 06′ N., 93° 53′ W., barometer 29.97. On the 7th encountered a wind from the E., barometer 29.80, in latitude 10° 01′ N., longitude 88° 23′ W.

The American S. S. *D. G. Schofield*, southward bound, experienced a hurricane from the northeast at 1 p. m. of the 6th, lowest pressure 29.96, in 15° 09′ N., 94° 27′ W. The gale continued to be experienced by the vessel until well into the 7th when, at 6 a. m., the wind was north-northwest 9, pressure 29.98, in 13° 27′ N., 93° 58′ W. On the 8th and 9th other gales were encountered, the highest force being 9 from the northeast, on the 9th, lowest pressure 29.85, in 10° 06′ N., 87° 31′ W. Several other vessels noted gales of force 8 to 10 at this time.

On the 20th to 23d high winds, though not exceeding 10 in force, occurred in the same region. The American S. S. *W. S. Rheem* early on the 21st was in a northwesterly gale, force 10, pressure 29.82, in 15° 52′ N., 93° 54′ W., and the American S. S. *Hampton Roads* on the 23d experienced a northeasterly gale, force 8, in 9° 42′ N., 86° 11′ W.

During the prevalence of these storms a strong norther occurred over the Gulf of Mexico.

Fog occurred more frequently in January than during the preceding month. On the China coast the phenomenon was noted on the 13th to 16th. Along northern and middle latitudes in west longitudes fog occurred on several days. None was reported from east longitudes, except as noted. Fog showed a considerable increase along the American coast, and was frequently observed outside the harbors of Seattle, San Francisco, and San Diego. One record comes from 10° 43′ N., 90° 19′ W., where it was observed on January 12 over a cool current of water.

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

ALFRED J. HENRY.

The month was cold and generally dry, the drought being most pronounced on the Pacific coast and thence eastward to the Rocky Mountains; precipitation was in excess of the normal over a narrow strip extending from the East Gulf States northeastward to New England (see inset chart of Chart IV).

The defect in temperature was due to the passage of four vigorous anticyclones across the country. The usual details follow.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

The month of January showed an increase in activity over the preceding month, particularly in the number and strength of the high-pressure areas. Twelve of the latter made their appearance in the Canadian Northwest and half of these followed a well-defined path southeastward down the Missouri Valley and thence eastward or east-northeastward to the Atlantic coast. During the evening of the 4th and the morning of the 5th there were two separate high-pressure areas with barometer reading over 31 inches, one nearly stationary over the northern Plateau and Rocky Mountain region and the other moving southeast over the middle and lower Missouri Valley.

The Alberta type was the most frequent LOW charted; but the more important storms of the month developed over southwestern districts.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

The outstanding feature of Table 1 is the subnormal monthly mean temperature at all stations and practically all levels. The most severe cold wave of the month occurred on the 4th and 5th. During this period minimum temperatures exceeded all previous January records at most of the aerological stations. At Ellendale the lowest temperature for the month, −39° C. (−38° F.), occurred at 3,500 m. and at Drexel, −26° C. (−15° F.), at 2,500 m. on the 4th; at Broken Arrow, −22° C. (−8° F.), at 650 m.; at Groesbeck, −10° C. (14° F.), at 1,050 m., and at Royal Center, −33° C. (−27° F.), at 900 m. on the 5th.

It is of interest to note some of the changes in the free air over Ellendale as shown by the kite records of these two dates (4th–5th). These are shown in the following table:

Free-air conditions above Ellendale, N. Dak., on January 4–5, 1924.

[Altitude (meters) above sea level.]

	Date.	Surface 444.	1,000	1,500	2,000	2,500	3,000	3,500
Temperature (°C.)	4	−31.0	−33.9	−33.5	−33.7	−34.6	−36.7	−38.9
	5	−31.8	−18.4	−15.7	−14.9	−13.6	−12.3	−11.6
Relative humidity (per cent)...	4	81	89	88	86	84	84	84
	5	83	48	29	17	21	25	29
Vapor pressure (mb.)...........	4	0.26	0.22	0.23	0.22	0.20	0.16	0.13
	5	0.27	0.59	0.46	0.29	0.40	0.53	0.66
Wind direction and velocity (m. p. s.)	4	NW. 7.6	N. 16.5	N. 16.6	N. 17.4	N. 18.6	N. 19.1	N. 19.6
	5	SSW. 5.8	W. 8.4	WNW. 8.5	NW. 9.6	NNW. 14.2	NNW. 18.7	N. 22.5

It will be observed that a pronounced rise in temperature, resulting in a strongly marked inversion on the 5th, occurred in the upper levels while the wind is shown to have changed to southerly at the surface but continued from a northerly point above. In spite of the small variation in the observed wind direction in the upper levels, however, there occurred a decided rise in temperature. It is also shown that this air on the 5th contained a much lower relative humidity while the absolute moisture content was greater than on the 4th. The weather map of the 4th shows Ellendale to have been in the eastern quadrant of a strong high pressure area; by the 5th this HIGH had moved southeastward so that Ellendale was slightly west of its northern border, a LOW was approaching from the northwest and another large HIGH was centered over the northern Plateau region. It is evident from an inspection of the weather maps that the "polar" air of which the first HIGH was composed had ceased influencing free-air conditions at Ellendale by the 5th and that on that date the upper NNW. winds were bringing in air which had followed a curved path round the northern border of the Plateau HIGH.

By the 6th the first HIGH had become centered over the lower Mississippi Valley bringing extremely low temperatures eastward to the coast. West of its center the winds being southerly caused the temperatures to be considerably higher than over the East Gulf and South Atlantic States. Therefore, owing to the appreciable difference in the air densities over these adjacent regions, a general west-to-east pressure gradient was set up. The upper winds on this date over Groesbeck and Broken Arrow revealed such a gradient. At these stations southerly winds in the lower levels veered to N. and NE. above 4 km. and remained so up to 9 and 10 km. These winds were of moderate velocity but above 10 km. the direction changed to WNW. and the velocity increased rapidly to 35 m. p. s. (78 m. p. h.) at which time the balloons were lost.

The northern quadrant of this HIGH controlled weather conditions over Royal Center on this date (6th) and in several respects these were of more than ordinary interest. The surface wind shifted from W. to a southerly quarter shortly after midnight and a pilot balloon released at 7:25 a. m. entered St Cu clouds 7 minutes later at 1,350 m. above ground. These clouds were moving from the WNW., while the surface-wind direction was SSW., the south component extending up to 1,000 m. above the surface. A kite flight started at 8:25 a. m., one hour later, showed a south component in the wind extending from the ground to more than 2,000 m. above, which fact is of special interest in that it is evident that the southerly wind appeared first in the lower levels. The striking effect of this southerly wind upon the free-air temperatures which prevailed the day before may be seen from the following table.

Free-air conditions above Royal Center, Ind., on January 5–6, 1924.

[Altitude (meters) above sea level.]

	Date.	Surface 225	500	1,000	1,250	1,500	2,000
Temperature (°C.)	5	−25.7	−28.6	−26.2	−28.2	−30.2	−29.5
	6	−20.6	−22.9	−16.3	−11.4	−7.2	−2.9
Relative humidity (per cent)	5	88	91	98	98	99	99
	6	85	80	57	43	46	91
Vapor pressure (mb.)	5	0.53	0.40	0.56	0.45	0.38	0.40
	6	0.84	0.63	0.84	0.99	1.54	4.38
Wind direction and velocity (m. p. s.)	5	W. 10.7	W. (*)	WNW. (*)	WNW. (*)	NW. (*)	NW. (*)
	6	SSW. 8.0	SSW. 16.0	SSW. 18.5	SW. 18.0	SW. 17.4	SW. 16.4

* Velocities missing.

Another interesting fact shown by the kite record of the 6th but not brought out in the above table was an increase in relative humidity from 35 to 93 per cent which occurred in the free air simultaneously with an increase in temperature from −8.4° to −2.5°. Such an occurrence is not frequently found, but instead, sharp changes in temperature are usually accompanied by opposite changes in relative humidity. However, in this instance, it was found that the St Cu clouds (8/10 in amount) observed at an altitude of 1,350 m. in the early morning dissipated rapidly a short time thereafter and by the time the head kite reached the height at which the clouds had previously obtained the relative humidity was still high (93 per cent) although the clouds themselves were not visible. It is conceivable that the south wind as it has been shown to have extended progressively upward dissipated the clouds and very likely a kite flight made a little later would have revealed a much lower relative humidity at this level.

On the afternoon of the 23d pilot-balloon observations made at Washington and Bolling Field, D. C., were strikingly similar, although showing extremely unusual wind velocities in the free air, the direction veered gradually from SW. at the surface to NW. at 2.500 m., but directly above this it backed again to W. A steady increase in velocity was found from 7 m. p. s. (16 m. p. h.) at the surface to 41 m. p. s. (92 m. p. h.) at 2,000 m., then a rapid fall to 9 m. p. s. (20 m. p. h.) at 3,000 m., increasing again to 44 m. p. s. (98 m. p. h.) at 4,000 m., followed by another drop to 15 m. p. s. (33 m. p. h.) at 5,000 m., at which elevation the balloon was lost. There have on several occasions in the past been observed rather similar conditions but none of such great magnitude. Some of these were cited in the "Free-air summaries" of October and November, 1922. The exact causes producing this phenomenon are not known, but it is obviously characteristic of the region undergoing change from the influences of a LOW to those of a HIGH and followed by a rapid movement of the barometric areas. This apparent stratification in the upper levels has been observed most frequently at the eastern stations and it seems rather certain that its most pronounced stage continues only for a brief period of time, although there has appeared some evidence of it even after 12 hours. It seems likely that large horizontal differences in temperature of rather local character at various levels are responsible for these abnormal winds but to determine this with certainty it will be necessary to have a much closer network of stations.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during January, 1924.*

TEMPERATURE (°C.).

Altitude. m. s. l. (m.)	Broken Arrow, Okla. (233 m.)		Drexel, Nebr. (396 m.)		Due West, S. C. (217 m.)		Ellendale, N. Dak. (444 m.)		Groesbeck, Tex. (141 m.)		Royal Center, Ind. (225 m.)	
	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 9-yr. mean.	Mean.	Departure from 3-yr. mean.	Mean.	Departure from 7-yr. mean.	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 6-yr. mean.
Surface..	0.2	−4.0	−9.6	−3.5	4.3	−2.3	−15.6	−4.5	3.9	−4.4	−6.9	−3.1
250	0.2	−4.0	......	......	4.3	−2.2	......	......	3.9	−4.1	−7.0	−3.0
500	−0.4	−4.0	−9.5	−3.3	4.0	−1.8	−15.5	−4.5	3.9	−3.6	−8.1	−3.0
750	−0.9	−4.1	−8.8	−3.0	4.0	−1.4	−15.4	−4.9	3.7	−3.6	−8.5	−3.0
1,000	−0.9	−4.0	−7.7	−2.8	3.9	−0.9	−14.1	−5.0	3.6	−3.8	−8.5	−3.0
1,250	−0.7	−3.7	−6.9	−2.6	3.8	−0.3	−12.9	−4.7	3.5	−3.7	−8.6	−3.0
1,500	−0.7	−3.4	−6.5	−2.1	3.3	0.0	−12.7	−4.5	3.0	−3.7	−9.0	−3.1
2,000	−2.2	−3.5	−7.5	−1.8	2.0	+0.5	−13.5	−3.9	1.6	−3.5	−9.7	−3.0
2,500	−4.6	−3.6	−9.4	−1.5	0.6	+0.9	−15.3	−3.6	−0.4	−3.1	−12.1	−3.7
3,000	−6.9	−3.5	−12.4	−2.0	−1.4	+1.0	−17.2	−2.9	−2.5	−3.1	−14.1	−3.5
3,500	−9.3	−3.4	−15.4	−2.5	−4.8	+0.1	−19.9	−2.8	−5.4	−3.3	−17.0	−3.9
4,000	−11.7	−3.1	−18.5	−2.8	−8.3	0.0	−22.9	−3.2	−8.4	−3.5	......	......
4,500	−14.4	−2.8	−22.1	−3.3	......	......	−26.1	−3.8	−12.3	−4.2	......	......
5,000	−17.1	−2.7	−25.7	−3.6	......	......	−29.5	−4.4	−15.9	−4.3	......	......

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during January, 1924*—Continued.

RELATIVE HUMIDITY (%).

Altitude. m. s. l. (m.)	Broken Arrow, Okla. (233 m.) Mean.	Departure from 6-yr. mean.	Drexel, Nebr. (396 m.) Mean.	Departure from 9-yr. mean.	Due West, S. C. (217 m.) Mean.	Departure from 3-yr. mean.	Ellendale, N. Dak. (444 m.) Mean.	Departure from 7-yr. mean.	Groesbeck, Tex. (141 m.) Mean.	Departure from 6-yr. mean.	Royal Center, Ind. (225 m.) Mean.	Departure from 6-yr. mean.
Surface	69	−1	88	+6	68	+1	80	−2	77	0	81	+2
250	69	−1	......	......	67	0	......	......	74	−1	80	+1
500	64	0	85	+6	63	0	79	−2	67	−5	73	−1
750	62	+2	78	+5	60	0	75	+1	63	−5	68	−1
1,000	59	+3	73	+6	58	0	72	+5	59	−3	63	−1
1,250	55	+3	68	+5	55	−2	68	+7	53	−4	58	−1
1,500	51	+3	65	+5	53	−3	66	+7	50	−4	57	+1
2,000	45	+2	64	+6	48	−3	66	+8	45	−4	59	+8
2,500	44	+3	60	+3	42	−6	68	+10	39	−7	57	+6
3,000	46	+6	62	+5	39	−7	68	+10	35	−8	58	+6
3,500	44	+5	61	+6	37	−9	64	+9	33	−8	62	+5
4,000	42	+6	59	+5	36	−10	65	+12	34	−4	......	......
4,500	41	+5	59	+5	......	......	69	+10	34	−3	......	......
5,000	43	+6	60	+6	......	......	69	+10	33	−3	......	......

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during January, 1924*—Continued.

VAPOR PRESSURE (mb.).

Altitude. m. s. l. (m.)	Broken Arrow, Okla. (233 m.) Mean.	Departure from 6-yr. mean.	Drexel, Nebr. (396 m.) Mean.	Departure from 9-yr. mean.	Due West, S. C. (217 m.) Mean.	Departure from 3-yr. mean.	Ellendale, N. Dak. (444 m.) Mean.	Departure from 7-yr. mean.	Groesbeck, Tex. (141 m.) Mean.	Departure from 6-yr. mean.	Royal Center, Ind. (225 m.) Mean.	Departure from 6-yr. mean.
Surface	4.50	−1.62	2.88	−0.50	5.95	−0.96	1.83	−0.57	6.81	−2.22	3.41	−0.56
250	4.47	−1.60	......	......	5.91	−0.91	......	......	6.60	−2.09	3.35	−0.52
500	4.08	−1.31	2.84	−0.40	5.62	−0.56	1.81	−0.56	6.06	−2.00	2.82	−0.55
750	3.78	−1.09	2.74	−0.22	5.39	−0.38	1.71	−0.47	5.54	−1.88	2.56	−0.49
1,000	3.51	−0.88	2.63	−0.17	5.24	−0.20	1.79	−0.33	5.13	−1.57	2.34	−0.43
1,250	3.28	−0.70	2.49	−0.16	4.93	−0.07	1.82	−0.23	4.54	−1.53	2.07	−0.43
1,500	3.06	−0.49	2.37	−0.12	4.54	−0.02	1.76	−0.17	4.02	−1.49	1.95	−0.33
2,000	2.49	−0.40	2.09	−0.08	3.45	−0.17	1.58	−0.12	3.08	−1.37	1.95	+0.06
2,500	2.15	−0.26	1.69	−0.13	2.53	−0.31	1.34	−0.06	2.26	−1.39	1.46	−0.18
3,000	1.84	−0.19	1.35	−0.18	2.06	−0.27	1.08	−0.02	1.77	−1.20	1.24	−0.19
3,500	1.48	−0.25	0.93	−0.30	1.52	−0.43	0.68	−0.09	1.31	−1.13	1.13	−0.14
4,000	1.22	−0.18	0.62	−0.35	1.23	−0.42	0.46	−0.07	0.99	−0.98	......	......
4,500	1.00	−0.20	0.39	−0.37	......	......	0.32	−0.31	0.69	−0.97	......	......
5,000	0.91	−0.20	0.28	−0.26	......	......	0.17	−0.38	0.49	−0.91	......	......

TABLE 2.—*Free-air resultant winds (m. p. s.) during January, 1924.*

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters). Mean. Dir.	Vel.	6-year mean. Dir.	Vel.	Drexel, Nebr. (396 meters). Mean. Dir.	Vel.	9-year mean. Dir.	Vel.	Due West, S. C. (217 meters). Mean. Dir.	Vel.	3-year mean. Dir.	Vel.
Surface	S. 12° W.	0.7	S. 32° W.	1.1	S. 69° W.	1.8	N. 89° W.	1.5	N. 50° W.	1.0	N. 76° W.	1.2
250	S. 12° W.	0.8	S. 29° W.	1.3	......	......	......	......	N. 51° W.	1.0	N. 79° W.	1.4
500	S. 24° W.	2.3	S. 26° W.	2.3	S. 84° W.	2.8	N. 83° W.	2.4	S. 64° W.	1.1	S. 86° W.	2.6
750	S. 44° W.	3.2	S. 34° W.	3.3	N. 86° W.	4.9	N. 77° W.	4.3	S. 58° W.	2.6	S. 83° W.	4.2
1,000	S. 55° W.	4.2	S. 48° W.	3.8	N. 82° W.	6.3	N. 76° W.	5.6	S. 65° W.	4.3	S. 82° W.	5.6
1,250	S. 82° W.	4.2	S. 66° W.	3.9	N. 79° W.	8.3	N. 75° W.	6.9	S. 71° W.	6.5	W.	7.5
1,500	W.	6.1	S. 66° W.	5.0	N. 79° W.	9.2	N. 74° W.	8.2	S. 70° W.	8.9	S. 85° W.	9.3
2,000	N. 86° W.	7.8	S. 78° W.	7.1	N. 76° W.	11.6	N. 73° W.	10.6	S. 73° W.	13.2	S. 89° W.	12.1
2,500	W.	8.3	S. 84° W.	8.4	N. 78° W.	13.3	N. 79° W.	12.8	S. 80° W.	16.4	N. 88° W.	15.2
3,000	N. 88° W.	8.5	N. 86° W.	9.7	N. 83° W.	13.4	N. 80° W.	14.2	S. 84° W.	16.8	S. 89° W.	16.6
3,500	N. 75° W.	10.2	N. 82° W.	10.4	N. 83° W.	16.3	N. 80° W.	15.4	S. 57° W.	14.2	S. 87° W.	15.7
4,000	N. 73° W.	12.0	N. 84° W.	13.4	N. 79° W.	18.5	N. 87° W.	17.0	S. 45° W.	15.6	N. 89° W.	15.0
4,500	S. 87° W.	8.7	S. 82° W.	10.5	N. 81° W.	17.1	N. 81° W.	17.3	......	......	......	......
5,000	N. 86° W.	9.0	N. 88° W.	11.9	N. 68° W.	16.6	N. 83° W.	16.6	......	......	......	......

Altitude, m. s. l. (meters).	Ellendale, N. Dak. (444 meters). Mean. Dir.	Vel.	7-year mean. Dir.	Vel.	Groesbeck, Tex. (141 meters). Mean. Dir.	Vel.	6-year mean. Dir.	Vel.	Royal Center, Ind. (225 meters). Mean. Dir.	Vel.	6-year mean. Dir.	Vel.
Surface	N. 66° W.	4.0	N. 58° W.	3.1	N. 10° W.	0.5	N. 34° W.	0.5	S. 57° W.	2.6	S. 52° W.	2.2
250	......	......	......	......	S. 60° W.	0.6	N. 74° W.	0.4	S. 52° W.	2.9	S. 51° W.	2.4
500	N. 71° W.	4.9	N. 61° W.	3.4	S. 38° W.	2.8	S. 52° W.	1.5	S. 54° W.	6.1	S. 59° W.	4.7
750	N. 64° W.	8.2	N. 64° W.	5.4	S. 51° W.	3.1	S. 60° W.	2.5	S. 60° W.	7.5	S. 66° W.	6.7
1,000	N. 56° W.	9.5	N. 62° W.	6.6	S. 63° W.	3.7	S. 62° W.	3.5	S. 65° W.	9.0	S. 75° W.	7.7
1,250	N. 51° W.	10.5	N. 63° W.	7.6	S. 68° W.	5.1	S. 71° W.	4.7	S. 69° W.	12.2	S. 79° W.	9.3
1,500	N. 55° W.	10.1	N. 64° W.	8.0	S. 82° W.	5.6	S. 76° W.	5.8	S. 70° W.	13.0	S. 82° W.	10.4
2,000	N. 56° W.	12.7	N. 64° W.	10.6	S. 85° W.	7.5	S. 79° W.	7.3	S. 69° W.	14.6	S. 82° W.	12.2
2,500	N. 56° W.	14.4	N. 64° W.	12.7	S. 78° W.	9.8	S. 80° W.	8.6	S. 79° W.	14.8	S. 88° W.	14.3
3,000	N. 59° W.	15.8	N. 68° W.	14.2	S. 71° W.	11.4	S. 79° W.	10.1	S. 78° W.	14.4	S. 87° W.	14.2
3,500	N. 62° W.	14.6	N. 67° W.	15.1	S. 69° W.	14.2	S. 82° W.	11.2	S. 45° W.	15.3	S. 76° W.	13.2
4,000	N. 61° W.	15.7	N. 60° W.	16.6	S. 65° W.	14.0	S. 74° W.	12.4	S. 45° W.	18.1	S. 66° W.	17.3
4,500	N. 46° W.	20.6	N. 50° W.	19.4	S. 67° W.	17.3	S. 73° W.	14.2	......	......	......	......
5,000	......	......	......	......	S. 82° W.	16.5	S. 88° W.	15.2	......	......	......	......

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist in Charge of Division.

PRESSURE AND WINDS.

January, 1924, will be remembered throughout much of the country as a month of rapid and well-marked variations in weather conditions. This was particularly noticeable in the great central valleys, where temperature changes especially were frequent and large, in fact at a number of points the average temperature variability was the greatest of record.

Anticyclones of a pronounced winter type moved from Canada into the United States at frequent intervals, pursued courses well to the southward, and brought severe cold to the Gulf and South Atlantic Coast States. The most important of these entered the far Northwest on the 4th with pressure readings, reduced to sea level, above 31 inches, and advanced into the central valleys by the morning of the 5th, and to the Gulf States during the following 24 hours. This high pressure area maintained its initial strength as it moved eastward and southward to a remarkable degree and gave the highest pressure readings ever recorded at numerous points in the southern Plains and Gulf States.

This anticyclone was attended by unusual cold over the Southern States from Texas eastward, approaching closely the temperatures experienced during the record-breaking cold wave of February, 1899, and caused immense damage in the fruit and vegetable growing regions along the Gulf and South Atlantic coasts, although the severe cold did not reach the important citrus and early vegetable districts of central and southern Florida, nor those of the lower Rio Grande Valley of Texas.

Other important anticyclones, attended by severe cold, moved southward and eastward from the Canadian Northwest about the end of the first decade, near the middle of the second decade, on the 20th to 21st, and again on the 25th and 26th.

At the beginning of the month an important cyclone, though attended mainly by only light rain or snow, was moving down the St. Lawrence Valley, and another was developing over the far Southwest. The latter moved eastward and, with another that appeared to have developed over the Great Lakes, gave extensive precipitation from the Mississippi Valley eastward, with heavy falls over the Ohio Valley and portions of the Gulf and Atlantic Coast States.

By the end of the first decade a cyclone of considerable proportions had developed over the middle Mississippi

Valley and its movement toward the northeast during the 10th and 11th was attended by precipitation over all eastern districts, and by gales along the North Atlantic coast. Precipitation was again heavy in the Ohio Valley and portions of the Gulf and Atlantic Coast States, and snow fell over most Northern States from the Dakotas eastward.

About the middle of the month cyclonic conditions developed in the Great Plains region and during the 16th and 17th precipitation overspread practically all central and eastern districts, heavy rains occurring over the Gulf and Atlantic Coast States, with more or less snow from the upper Mississippi Valley eastward.

The latter part of the month had less cyclonic activity, though an important disturbance moved from the lower Mississippi Valley northeastward to the Great Lakes and New England from the 24th to 26th, attended by important rains in the Atlantic coast districts, snows in the Great Lakes region and to the eastward, and high winds along the middle and north Atlantic coast.

The month as a whole was remarkably free from severe storms on the Pacific coast, a condition that has now persisted for several months.

The average pressure for the month conformed to the type usually associated with a cold month, although the mean values were universally materially higher than normal, and particularly so in the mountain districts of the West.

Compared with the means for the preceding December, those for January were higher in all districts by considerable amounts, though this is somewhat unusual, as under normal conditions January pressures are lower than those for December in most districts from the lower Mississippi Valley northeastward to New England, and from Texas northwestward to Oregon and southern Idaho.

The highest winds of the month were mainly along the north Atlantic coast, the maximum reported, 80 miles per hour, occurring at Atlantic City, N. J., on the 16th. On the north Pacific coast, where high winds are usually frequent at this period of the year, they were notably absent until near the end of the month.

In the region of the Great Lakes pressure variations were frequently large and wind movement was greatly augmented. At Buffalo, N. Y., the average wind velocity was the greatest of record for any month.

On account of the turbulent state of the atmosphere from the Rocky Mountains eastward the prevailing directions of the winds varied greatly, though they were mainly from northerly points in the Gulf and Atlantic Coast States, from the south in the Middle Plains, and from westerly points along the northern border. In the districts from the Rocky Mountains westward they were mainly outward from the high pressure area central over eastern Oregon, southern Idaho, and the northern portions of Utah and Nevada.

TEMPERATURE.

The outstanding feature of the temperature conditions existing during the month was the sharp change from unusual warmth that had prevailed during the two preceding months over much of the country to almost steady cold that set in near the close of the year and continued over the greater part of the month.

In the central valleys and the Northwest low temperatures persisted to such an extent that, but for the few days of unusual warmth at the end, the averages for the month would have equaled or approached closely those

attained in January, 1918, one of the coldest months of record.

Save for the severe cold wave that visited the Southern States on the 5th and 6th, the temperatures were not abnormally low, but the periods of warmth, though frequent, were unusually short and the returns to cold were quick and sharp.

The more important cold periods were at or near the beginning of the month in the far Northwest, and over considerable portions of the Great Plains and Southwest; and on the 5th and 6th over most other districts, except that in the Northeastern States the lowest temperatures did not occur until near the end of the last decade.

The low temperatures in the Southern States on the 5th to 7th, as stated elsewhere, approached closely in many cases those of February, 1899, though fortunately the development of clouds with some rain over the southern and central portions of the Florida Peninsula hindered the advance of severe cold into those districts, and no serious damage resulted to the large citrus and early vegetable interests of those sections.

In addition to the immense damage to vegetation reported from the Gulf and South Atlantic coast sections, much loss was sustained from the severe cold throughout the South on account of frozen water pipes, automobile radiators, etc.

Over the Pacific coast States some unusually low temperatures occurred on the 2d and 3d, particularly in California, where damage to citrus interests appears to have been important. In the Northeastern States moderate temperatures continued, as during the preceding month, except for the last decade.

The lowest temperature reported during the month was 53° below zero, which occurred at a point in Montana on the 1st.

The highest temperatures for the month were mainly near the end, particularly from the Rocky Mountains and northern Great Plains westward. Elsewhere they varied greatly as to dates.

The averages for the month were below normal over the greater part of the country, the only exceptions being the Northeastern States and the immediate Atlantic coast districts as far south as Virginia, the southern portion of Florida, and small areas along and near the coasts of California, Oregon, and Washington. Over all interior districts the month was colder than normal, the departures ranging up to nearly 8°.

PRECIPITATION.

Considering the country in its entirety the month may be classed as one of largely deficient precipitation, the only States having amounts above the normal, as a whole, being those of the Atlantic and Gulf coasts, the Appalachian Mountain districts, and portions of the Great Lakes region. All other States had averages less than normal, although small areas in a few had normal or slightly larger amounts. In general precipitation east of the Mississippi Valley was well distributed through the month, sufficient for present needs, and in the southern and more eastern districts the falls were generous, some localities receiving up to 8 inches or slightly more.

Between the Great Plains and the Rocky Mountains there was little precipitation, and many large areas in this region had no measurable amounts. In the Plateau region there was little precipitation, particularly in the southern portions where at certain points clouds were entirely absent and sunshine was 100 per cent of the

possible, the greatest of record for January. Over the Pacific coast sections the precipitation was practically everywhere less than normal, the deficiencies being large in California, where similar conditions have persisted for several months.

SNOWFALL.

In nearly all sections of the country the snowfall for January was less than normal, although considerable areas had a slight covering during much of the month. In the districts east of the Rocky Mountains the greatest depths were reported from northern New York, the interior of New England, and over the upper Lake region, but no particularly heavy falls occurred during the month. In general, not much interference to business interests resulted from drifting snow, save in Iowa and portions of adjoining States, where traffic was interrupted following the storm of the 8th and 9th and again about the 15th.

In the western Mountain districts the snowfall during January was likewise less than normal, though in portions of the middle Rocky Mountains there were more generous amounts.

In California and the adjacent portions of Oregon and Nevada the snowfall was unusually light, and in some sections probably the lightest of record for January.

The stored amounts in the higher mountains at the end of the month, where great importance attaches to the probable supply of water for irrigation and power purposes, are nearly everywhere less than normal.

Over the northern districts from the Great Lakes westward ice of sufficient thickness to harvest formed early in the month, and its storage progressed satisfactorily, through the month. In the more eastern districts, however, where ice is gathered for commercial purposes, it did not acquire a satisfactory thickness until late in the month.

RELATIVE HUMIDITY.

Despite the absence of appreciable precipitation over the Great Plains and mountain districts of the West, the relative humidity in these regions was mainly above normal. Over the Pacific coast States, however, particularly in California, the drought conditions were reflected in the lowered percentage of the relative humidity, which was in some cases nearly 20 per cent less than normal. On the other hand over the Atlantic and Gulf coast States, despite the fact that precipitation was generous to heavy, the relative humidity was also less than normal.

SEVERE LOCAL STORMS, JANUARY, 1924.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path, yards.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Brooklyn, N. Y	1					Wind	A number of houses in course of construction were wrecked.	Daily News (New York).
Meridian, Miss. (4 miles southwest of).	3	1-2 a. m.				Tornado	Four homes wrecked and a store damaged; 1 person injured.	Official, U. S. Weather Bureau.
Rome, Ga.	10	P. m.				Wind	Considerable property damaged and 2 persons injured.	Star (Anniston, Ala.).
Central and northeastern Alabama.	10	...do.		2		...do.	Several dwellings damaged and a number of barns and sheds wrecked; some livestock killed; several persons injured.	Do. Pensacola News (Fla).
New York, N. Y., and vicinity.	16-17			6		High winds	General damage done; many persons injured.	Official, U. S. Weather Bureau.

STORMS AND WEATHER WARNINGS.

By EDWARD H. BOWIE, Supervising Forecaster.

WASHINGTON FORECAST DISTRICT.

The month of January was notable for the frequency and pronounced character of its temperature changes, and this was particularly true of the Middle West and the Northwest, where a number of pronounced cold waves, that came southward out of Canada, reduced the temperatures for the month greatly below the normal. While these cold waves in several instances advanced eastward to the Atlantic coast and southward to the Gulf of Mexico, they were greatly modified in severity, and consequently no record-breaking low temperatures occurred except over limited areas. The eastward passage of high and low pressure areas occurred with great frequency, and as a result there were marked changes from high to low temperature and frequent changes from fair to falling weather. Moreover, the issue of storm warnings for the coastal waters was rather more than is ordinarily required for the month of January. The notable storm of the month occurred on the 16th, when southerly gales broke the airship *Shenandoah* from its mooring mast at Lakehurst, N. J.; and it was only because of a lull in the wind shortly thereafter was her crew able to bring her back to her hangar at Lakehurst. At noon of the day in question the Bureau of Aeronautics of the United States Navy Department was advised that the wind at Lakehurst would likely reach a velocity of 60 miles an hour or more during the late afternoon and early night.

The month opened with high barometric pressure general east of the Rocky Mountains, but with a low-pressure area of increasing intensity over the western Plateau region. This disturbance lost intensity in moving southeastward during the night of the 1st, but on the morning of the 2d there were unmistakable evidences of the formation of a center of low pressure over the northwestern portion of the Gulf of Mexico. This disturbance developed, as foreseen, and advanced northeastward and produced general precipitation over and east of the Mississippi Valley during the succeeding 36 hours. This was in turn followed by an area of high barometric pressure of great magnitude which on the morning of the 3d had its crest over the Northwestern States, and made necessary the issue of cold-wave warnings for practically all parts of the Washington Forecast District. These warnings were issued on the 3d, 4th, and 5th as the cold wave advanced eastward. On the 5th, as this high pressure was advancing eastward and the pressure falling rapidly off the Atlantic coast, storm

warnings were displayed on the Atlantic coast southward from New England to Jacksonville, Fla., and on the 6th when a disturbance of increasing intensity was central off Cape Cod, northwest storm warnings were continued at and north of Delaware Breakwater. The evening of the same day and for the same stretch of coast the warnings were changed to southwest, for strong backing winds attending the eastward movement of a disturbance of pronounced character that had its center north of the Great Lakes. This disturbance passed rapidly eastward to the Gulf of St. Lawrence with strong winds and gales along the coast where storm warnings were displayed; and it was followed by rapidly rising pressure and decidedly colder weather along the northeastern border, cold-wave warnings being ordered the morning of the 7th for northeastern New York and northern New England.

On the 10th when a disturbance of pronounced character was central over the Mississippi Valley and advancing eastward, small-craft warnings were displayed over the Mobile and Pensacola storm warning districts, northeast storm warnings on the New England coast and southwest storm warnings along the coast at and between New York City and Savannah, Ga. This disturbance advanced steadily east-northeastward, and storm winds were general during the night of the 10th and during the 11th along the Atlantic coast. The highest velocity reported was 72 miles an hour from the south at New York City and Atlantic City. Relatively tranquil weather prevailed from the 11th until the 15th and 16th, although storm warnings were displayed on the Atlantic coast from Delaware Breakwater to Boston on the 13th when a disturbance of moderate intensity was central off Cape Hatteras. It moved northeastward, its center, however, keeping off the coast, and no winds of gale force occurred over the area where storm signals were displayed. On the 15th, the pressure was abnormally high in the Atlantic States and low in the Mississippi Valley, with a center of minimum pressure over Louisiana. The system of low pressure was advancing northeastward and the Louisiana disturbance increasing in intensity. Therefore, in the early morning small-craft warnings were displayed on the east Gulf coast and later in the day southeast storm warnings were displayed on the Atlantic coast at and between Jacksonville, Fla., and the Virginia Capes. On the morning of the 16th when the center of the disturbance was over Indiana, southeast storm warnings were displayed on the Atlantic coast north of the Virginia Capes and cold-wave warnings were ordered for Tennessee, the Ohio Valley, and the lower Lake region. This disturbance is the one referred to in the opening paragraph as being the most intense of the month on the Atlantic coast. The highest wind velocity reported was 76 miles an hour at Atlantic City, N. J.

On the 19th and 20th the pressure rose abnormally over the northwest following the eastward movement of a belt of low pressure which extended southward from the northern border to the Gulf of Mexico, and as the change to colder therewith was pronounced, it was necessary on the 19th and 20th to issue cold-wave warnings for practically all parts of the Washington Forecast District and northwest storm warnings on the morning of the 20th for the Atlantic and Gulf coasts. It was also necessary on the 22d to issue southwest storm warnings for the Atlantic coast north of Delaware Breakwater and to continue these storm warnings on the 23d, on which date cold-wave warnings were also displayed over northeastern New York and northern New England. On the 24th, when the barometric pressure was quite high in the Atlantic States, low over the lower Mississippi Valley and high and rising rapidly in the northwest, southeast storm warnings were displayed on the east Gulf and Atlantic coasts and cold-wave warnings were displayed in western Tennessee and Kentucky. On the 25th cold-wave warnings were displayed over practically the entire Washington Forecast District and storm warnings were continued on the Atlantic coast at and north of Cape Hatteras. The severity of this storm was such as to require that storm warnings be continued on the 26th at and north of Delaware Breakwater.

CHICAGO FORECAST DISTRICT.

In the Chicago forecast district, January, 1924, was a rather notable month. Over the Missouri and middle and upper Mississippi valleys, as well as in the extreme western upper Lake region, it was, generally speaking, the coldest January since the memorable month of that name in 1918. Sudden and marked alternations in temperature were a feature of the month, and over at least a limited area (Chicago and its vicinity) the mean daily variability of temperature exceeded all previous records of this character. As might be inferred from the foregoing, cold waves were of frequent occurrence, and in one or two instances these were of great severity in portions of the district.

Cold wave warnings.—In this section of the REVIEW for December, 1923, reference was made to the culmination, in the first week of the month now under discussion, of the cold wave that affected the district during the closing days of December, and which finally resulted in the lowest temperatures in a decade or more at many points. The conditions during the few days preceding January 5 (when the crest of the cold was reached) were as follows: On the 1st and 2d a pronounced katallobar, with an attendant marked rise in temperature from the prevailing zero values, moved rapidly east-northeastward from the southern Rocky Mountain Plateau to the lower Lake region. This was closely followed by an anallobar of similar character, with the result that a decided fall in temperature occurred on the night of the 2–3d throughout the upper Mississippi and the middle and lower Missouri Valleys, the fall reaching the proportions of a cold wave over a large part of the area named. Cold-wave warnings were issued on the night of the 2d for northeastern Michigan, and these were verified. Twelve hours later the warnings were extended to include eastern Lower Michigan and eastern and southern Indiana. While a considerable fall in temperature occurred over these areas, a technical verification was not attained. In the meantime a high pressure area with attendant very low temperatures had been developing over British Columbia, and at the same time increasing in magnitude. By the morning of the 3d the barometer at Kamloops was 30.68 inches and the temperature —10°, while an area of falling barometer was over the middle Rocky Mountain Plateau. Twelve hours later this latter area was forced to western Texas, and by the morning of the 4th to extreme southern Texas, whence it moved rapidly northeastward, in deepened form, to the upper Ohio Valley on the night of the 4th. During the passage of this katallobar a portion of the British Columbia high area moved to the upper Missouri Valley, the barometer at the same time continuing to rise, so that readings were 31 inches or somewhat above over a considerable area on the 4th. By the early night of that date severe

cold prevailed southward over Iowa, the temperature at Des Moines at 7 p. m. being 12° below zero. During the succeeding 12 hours the cold wave swept southeastward to the Ohio River with resulting temperatures (as previously mentioned), the lowest in more than a decade at many points. At Chicago, Ill., the minimum of —16° equaled the low record made on January 7, 1912. The reaction from this cold wave was very marked, and over some areas, particularly in the northern Plains States, the 24-hour rises amounted to from 50° to 60°.

The next cold wave appeared on the 9th in Saskatchewan and Manitoba, coming apparently from the region east of Alaska. At the same time a well-developed disturbance was central near the Kansas-Colorado boundary. Accordingly, warnings for a moderate cold wave were issued for most of the upper and middle Mississippi Valley, the Central Plains and Wyoming. Although a considerable fall in temperature occurred over the areas in question, verification was not attained except over a limited area.

On the night of the 14th a new cold wave appeared over the Canadian Northwest. During the following 24 hours the cold overspread the district as far as the upper Mississippi and middle Missouri Valleys, and the remainder of the district by the morning of the 17th, zero weather prevailing southward as far as St. Louis, Mo. The warnings issued in connection with this cold wave were fully verified.

In rapid succession to the cold wave just referred to, conditions again became critical over portions of the Northwest, so that warnings were issued on the night of the 17th for western Nebraska, northwest Montana, and Wyoming. These were verified, but the extension of the warnings on the morning of the 18th over Minnesota and northwestern Iowa was not justified.

On the morning of the 19th the temperature in southern Missouri, southern Illinois, and Indiana was comparatively high, in connection with a trough of low pressure that overlay those areas. At the same time a marked high area with attendant low temperatures was present in the Northwest—conditions apparently favorable for a cold wave in the areas named. Accordingly, warnings were issued, and the cold wave occurred as forecast.

By the morning of the 22d the barometer was rising rapidly throughout the Canadian Northwest, and based largely upon this condition cold wave warnings were issued for most of the northern States of the district. Subsequent developments, however, were such that the cold waves that occurred were confined to northeastern Montana, North Dakota and Minnesota.

The final cold wave of the month began on the 24th, and it swept the entire district during the following two days. In most cases the general warnings that were issued were verified. Over a considerable area the 24-hour fall in temperature ranged from 35° to 40°.

The reaction from this last cold wave continued during the remainder of the month with the result that the mildness of the closing days had a marked effect on the final average temperature of the month, increasing it by several degrees. Otherwise the month would have been more nearly comparable with the cold January of 1918.

Warnings for Lake Michigan.—Stormy weather prevailed on Lake Michigan on several occasions during the month, and with one or two exceptions timely advices of impending conditions were issued. The first strong winds to occur were in connection with the reaction from the severe cold wave of the 5th. A low-pressure area moved southeastward from the Canadian Northwest on the 5th and 6th, which, in connection with the great cold high area that overlay the South on the 6th, created a sharp gradient over Lake Michigan, with the result that strong winds and moderate gales occurred on that date. The advisory warning in this connection was issued on the morning of the 6th.

The next advisory for Lake Michigan was that on the 9th in connection with the storm that crossed the Great Lakes on the 10th. At some points on Lake Michigan moderate gales occurred. The advisory warning was continued on the 10th.

On the 16th a warning was issued in connection with the disturbance that preceded the cold wave of the 17th. The storm center passed eastward just south of Lake Michigan, and although the gradient was rather steep, no storm winds were reported from points on the Lake.

So far as pressure conditions were concerned, the reaction from the severe cold wave of the 21st–22d was quite similar to that which occurred on the 6th. Advisory warnings were issued on both the 21st and 22d, and strong southwest winds and moderate gales were general on Lake Michigan on those dates.

The last advisory warning for Lake Michigan was issued on the night of the 24th in connection with the cold wave that was about to overspread the Lake. At that time an elongated disturbance was advancing eastward across the Lake region with increasing strength. By the morning of the 25th the disturbance had become a storm of the first magnitude with its center over Georgian Bay, and a barometer reading of 29.24 inches at Parry Sound. At the same time the pressure was about 30.60 inches over the upper Missouri Valley. Press dispatches indicate that the 25th was one of the stormiest days in years in lower Michigan.

Stock interests were advised on the 9th, 15th, 22d, and 24th of expected weather conditions that might prove adverse.—*C. A. Donnel.*

NEW ORLEANS FORECAST DISTRICT.

Unseasonably cold weather prevailed throughout the district, with some intense cold waves. The first cold wave of the month occurred at El Paso, Tex., on the 3d, for which warning was issued on the 2d. Cold-wave warnings were issued on the evening of the 3d for Oklahoma, the northern portion of west Texas, and the northwest portion of east Texas, and extended on the morning of the 4th over Arkansas. Conditions were such on the 4th that special observations were called for and these showed a rapid movement of the high pressure and cold wave towards the south, and livestock, cold-wave and freezing-temperature warnings were extended to the West Gulf coast. The cold wave came with unusual rapidity, and in parts of the district was the coldest during the last five years. Much saving of property resulted from the warnings.

Another severe cold wave overspread the interior of the district on the 10th, for which warnings had been issued on the 9th. Warnings were issued on the 16th for a moderate cold wave which occurred over the northern portion of the district on the 17th. Warnings were issued on the 19th for a severe cold wave which overspread the greater portion of the district on the 20th and 21st, with temperature below freezing to the Gulf coast. No cold wave of any consequence occurred without warning. Storm warnings were displayed on parts of the Texas coast on the 4th, 19th, and 20th, all of which were verified. Storm warnings on the Louisiana coast were only partially verified but conditions were so

threatening that they were called for. Small-craft warnings were displayed on parts of the coast on the 2d, 4th, 9th, 10th, and 15th. No storms occurred without warning.

"Norther" warning was issued for Tampico, Mexico, on the afternoon of the 20th, and was justified.—*I. M. Cline.*

DENVER FORECAST DISTRICT.

Storms of considerable intensity which moved eastward from the southern Rocky Mountain Plateau on the 1st–2d, 8th–9th, and 14th–15th were attended by occasional snow in nearly all of the district except the extreme southwestern portion. The LOW of the 1st was followed by a cold wave in southern Colorado, northern New Mexico, northeastern Arizona, and southern Utah. A disturbance which appeared in western Canada on the 13th advanced slowly southward and was followed during the period from the 15th to the 17th by a HIGH from Alberta, attended by a cold wave that reached extreme southeastern New Mexico on the last-named date. Another LOW that was also followed by a cold wave on the eastern slope advanced southeastward from British Columbia during the 16th, 17th, and 18th, the cold wave extending to southeastern New Mexico by the morning of the 20th. During the last decade of the month, high pressures prevailed on the middle Rocky Mountain Plateau, with low pressures to the northward and eastward. These conditions were attended by generally fair weather in the district and by moderate temperatures on the eastern slope.

On the morning of the 1st, livestock warnings were issued for southwestern Colorado, northern New Mexico, northeastern Arizona, and southeastern Utah. At 2 p.m. of the same day, warnings of a moderate cold wave, based upon special observations, were issued for western Colorado, northern Arizona and Utah "to-night" and for north-central and north-western New Mexico "to-night and Wednesday." Warning of a moderate cold wave in northern New Mexico was repeated at 8 p. m.

Snow fell during the day of the 1st in western Colorado, northwestern New Mexico, northern Arizona, and eastern Utah and during the following night in western Colorado, north-central New Mexico and southern Utah, with the heaviest falls in extreme southwestern Colorado and northeastern Arizona. The cold-wave warnings were fully verified, except in northwestern Colorado and northern Utah.

At 8 p. m. of the 3d, warnings of a severe cold wave were issued for southeastern Colorado and eastern New Mexico, and warnings of a moderate cold wave were extended to extreme southeastern New Mexico on the morning of the 4th. The warning was verified in southeastern Colorado and that portion of New Mexico east of the mountains.

Warnings of a moderate cold wave in eastern Colorado "during the next 24 hours" were issued at 2 p. m. of the 15th and were repeated at 8 p. m. of the same date. The warnings were completely verified.

At 8 a. m. of the 16th, severe cold-wave warnings and livestock warnings were issued for eastern Colorado and northeastern New Mexico. Snow occurred during the same day in central and eastern Colorado and extended to extreme northeastern New Mexico during the night. The cold-wave warnings were verified in eastern Colorado and that portion of northeastern New Mexico east of the mountains.

A warning of a cold wave that failed of verification was issued for extreme southeastern New Mexico at 8 p. m. of the 16th. The failure was due to the fact that an expected rapid increase in pressure did not occur in the southeastern portion of the forecast district.

Warnings of a severe cold wave "to-night and Saturday" and livestock warnings for eastern Colorado, with warnings of a moderate cold wave for extreme northeastern New Mexico, were issued at 8 a. m. of the 18th. Severe cold-wave warnings for eastern and central Colorado, with warnings of a moderate cold wave for extreme northeastern New Mexico, were repeated on the evening of the same date. Light snow fell in eastern Colorado during the following night and the next day, with a fall in temperature throughout all of the territory specified that was amply sufficient to justify the forecasts.

On the morning of the 19th, warnings were distributed of a severe cold wave in southeastern Colorado and of a moderate cold wave in extreme eastern New Mexico. The warning was completely verified.

Local cold waves for which no warning was issued occurred at Durango on the morning of the 10th and at Flagstaff on the morning of the 17th.

Forecasts of freezing temperatures were issued for south-central and southeastern Arizona on the 2d, 4th, and 19th; for south-central Arizona on the 13th, 15th, and 17th, and for southeastern Arizona on the 9th. The warnings were generally verified.

Frost warnings for Arizona were issued as follows: 1st, 3d, and 9th, heavy in south portion; 2d, 4th, 17th, and 19th, heavy in extreme southwestern portion; 5th and 11th, frost south-central portion; 12th, heavy in south-central portion; 13th frost extreme southwestern portion; 14th and 16th, heavy frost in south-central and southwest portion; 15th, heavy in southwest portion; 18th, frost in south-central portion; 23d, 24th, 25th, and 26th, frost in southwestern portion. The warnings were verified as a rule by the occurrence of frost or temperatures at which frost might be expected.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT.

The controlling factors of the weather over the Pacific slope during January, 1924, were the persistence of an area of high pressure over the intermountain region while the pressure remained comparatively low over British Columbia and Alberta. This pressure distribution favored the passage inland of storms from the north Pacific at a high latitude, and is the typical condition to cause dry weather over the central and southern portions of the Pacific coast.

Warnings of severe frosts in California were issued 17 times, and while some damage was done to citrus fruit and vegetables, no damaging frost occurred without warnings.

Storm warnings were ordered as follows: Southeast warnings from Tatoosh to Point Reyes on the 2d; southeast warnings from Eureka to Point Reyes on the 25th; southwest warnings at Washington coast stations on the 26th; southwest warnings at all stations from Point Reyes north on the 27th; southwest warnings Washington and Oregon stations on the 29th; warnings changed to southeast at Washington and Oregon stations on the 30th; southeast warnings continued at Washington and Oregon stations on the 31st. The warnings were mostly verified and from gales reported a short distance at sea all are believed to have been justified.—*G. H. Willson.*

RIVERS AND FLOODS.

H. C. FRANKENFIELD, Meteorologist.

At the close of the year 1923, the Ohio River and its southern tributaries were rising rapidly. There was a slight fall in the Monongahela River on the morning of January 2, 1924, and in the Ohio River above Wheeling, W. Va., on the following morning. However, the heavy and general rains of January 2 and 3 checked the fall abruptly, and on January 4 a general rise was again in progress, although at a very slow rate below Louisville, Ky., as the river had receded but little from the comparatively high stages of the preceding month, and had again passed the flood stage from Evansville to Mount Vernon, Ind., on January 2 and 3. Warnings for all the floods were issued regularly, beginning with January 3.

In the Pittsburgh district the crest stages on January 4 ranged from 2 to a little more than 5 feet above the flood stages, except in the vicinity of Wheeling, W. Va., where the crest was only 0.4 foot above the flood stage of 36 feet.

At Pittsburgh the crest stage on January 4 was 27.4 feet, 5.4 feet above the flood stage. The stage of 29 feet that had been forecast would have been reached and higher stages would have occurred below had not the cold wave of January 4 and 5 checked the rise. While some inconvenience resulted and some expense was occasioned through the removal of portable property that was subject to injury from overflow, no damage of consequence occurred.

In the Parkersburg, W. Va., district the crest stages were but little above the flood stage, except at Point Pleasant, W. Va., at the mouth of the Great Kanawha River, where the stage was 5.9 feet above the flood stage of 40 feet. There were no reports of damage or loss.

The flood was also moderate in the Cincinnati, Ohio, district, and there were no losses except about $10,000 due to moving of portable property and suspension of business. The value of property saved by the warnings was about $50,000.

Below the mouth of the Kentucky River the floods were rather more severe owing to the greater increments from the Kentucky, Salt, and Green Rivers, and a moderate flood in the Cumberland River. As will be seen in the table, these rivers were well above the flood stage at all points on January 4, and only the cold wave prevented still higher stages. The crest stages at Ohio River stations in the Louisville district occurred between January 9 and 14, and ranged from 2.9 to 9.5 feet above the flood stage, the highest relative stages occurring at the lower gage at Louisville and at Cloverport, Ky. The Kentucky River flood delayed the crest at Louisville somewhat, and the severe flood in Salt River contributed to the flattening of the flood plane between Louisville and Cloverport.

Losses in the Louisville district were small, about $5,600 only having been reported. Much property in cities, and hay, corn, and fodder in farming districts were removed to places of safety, and the value of property saved through the warnings was reported at $90,000. The usual inconvenience from flooded roads, etc., was reported. It is noted that the dissemination of warnings was greatly facilitated through the radiophone service of the Louisville Courier Journal and the Louisville Times.

In the Evansville, Ind., district and that portion of the Cairo, Ill., district above the mouth of the Cumberland River the crests were from 7.5 to 9 feet or more above the flood stages, Shawneetown, Ill., reporting a stage of 44.2 feet on January 27, 9.2 feet above flood stage. No flood stages were reported below Shawneetown, but the stages at Paducah, Ky., and Cairo, Ill., were 42.7 and 43.7 feet, respectively, or 0.3 foot and 1.3 feet below flood stage.

Notwithstanding the high stages of the river, the reported losses were very small, only about $2,000 in corn left in the fields. No statement can be made of property saved through the warnings, which were frequent, timely, and accurate. However, it was estimated that the value of property saved was several hundred thousands of dollars, largely in livestock and other property removed from the low bottoms.

The floods in the Cumberland and Tennessee Rivers were moderate and were well forecast, and the damage reported was inconsiderable, only $2,370. The value of property saved through the warnings was given as $4,700 in the Cumberland Valley. No figures are available for the upper Tennessee River, but great quantities of ties, lumber, cotton, and merchandise at landings were removed to higher ground upon receipt of the warnings.

The losses along the lower Tennessee River and the Ohio River from Shawneetown southward were about $6,000, while the value of property saved was given as $61,000, which included the Mississippi River from Cairo, Ill., to New Madrid, Mo.

Floods were also quite general, as a rule, in the northern tributaries of the Ohio River, but all were moderate. However, except in the Hocking River of Ohio, they occurred immediately following the substantial rains of January 10, when the rivers were still comparatively high from the previous rise. The flood conditions also extended over the drainage areas of the Wabash and Green Rivers. Warnings were issued at the proper time, and there were no losses of consequence.

The crest of the flood passed into the Mississippi River on January 14, reaching Memphis, Tenn., on January 18, Vicksburg, Miss., on January 27, and New Orleans, La., on January 31. Flood stage was not reached, except at New Madrid, Mo., where there was a crest of 34.2 feet on January 15–17, 0.2 foot above flood stage.

The heavy rains of January 16 and 17 over the South Atlantic States were followed by moderate floods in many of the rivers. They were forecast at the proper time and accurately, except in one or two instances in which the manipulation of the water for power purposes interfered with the natural flow. No damage of consequence occurred, and a large quantity of livestock, etc., was removed from lowlands upon receipt of the warnings. Along the James River of Virginia, property to the value of $11,000 was saved.

An average rainfall of at least 3 inches over the drainage area of the Tombigbee River of Alabama and Mississippi from January 1 to 3, inclusive, brought the Tombigbee and Black Warrior Rivers to flood stage within two days. At Tuscaloosa, Ala., on the Black Warrior River the crest stage was 52.7 feet at 8 p. m., January 4, or 6.7 feet above flood stage, while at Demopolis, Ala., on the main stream, the crest was 50.8 feet on January 18, or 11.8 feet above flood stage. The river at Demopolis remained above the flood stage from January 4 to 29, inclusive, but only from January 4 to 6, inclusive, at Tuscaloosa. Warnings were first issued on January 3. A limited area of land was overflowed, but the losses were apparently very small. Property to the value of $15,000 was reported as having been saved through the warnings.

One statement read: "I have 200 cows; there were thousands of cows in the lowlands here, and owing to your service but few were lost."

The same general rain conditions covered the Pearl and West Pearl River districts of Mississippi and southeastern Louisiana, and there were moderate floods in the Pearl River. The West Pearl River had been in flood at the beginning of the month and continued so at its close. Logging operations were suspended, but there was no damage of consequence as virtually all the crops in the fields had been destroyed by the cold wave of January 6 and 7.

At different times during the month there were moderate local floods in the Sulphur, Cypress, Sabine, and Trinity Rivers of Texas. Warnings were issued when necessary, and no material damage was done.

The flood in the upper Gila River of Arizona subsided after January 5, the crest stage at Kelvin, Ariz., having been 6.4 feet on December 29, 1923, or 1.4 feet above flood stage.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Unadilla:	*Feet.*			*Feet.*	
New Berlin, N. Y.	8	12	12	9.5	12
Chenango:					
Sherburne, N. Y.	8	12	12	8.2	12
James:					
Columbia, Va.	18	17	18	23.5	17
Richmond, Va.	10	18	19	11.3	18
Roanoke:					
Randolph, Va.	21	18	18	22.6	18
Weldon, N. C.	30	18	20	37.3	19
Dan:					
Danville, Va.	8	17	17	8.9	17
Cape Fear:					
Elizabethtown, N. C.	22	19	19	22.8	19
Peedee:					
Cheraw, S. C.	27	18	19	29.8	19
Mars Bluff, S. C.	17	20	25	18.6	23
Santee:					
Rimini, S. C.	12	18	([1])	15.9	22
Ferguson, S. C.	12	19	([1])	13.8	23
Catawba:					
Catawba, S. C.	12	18	18	14.0	18
Congaree:					
Columbia, S. C.	15	18	18	15.6	18
Broad:					
Blairs, S. C.	15	17	18	18.4	18
Saluda:					
Chappells, S. C.	14	17	19	15.0	18
Oconee:					
Milledgeville, Ga.	22	25	25	23.7	25
EAST GULF DRAINAGE.					
Tombigbee:					
Aberdeen, Miss.	33	6	7	33.2	6
Lock 4, Demopolis, Ala.	39	4	29	50.8	18
Black Warrior:					
Lock 10, Tuscaloosa	46	4	6	52.7	4
WEST GULF DRAINAGE.					
Pearl:					
Jackson, Miss.	20	3	31	26.6	17
Columbia, Miss.	18	17	22	18.8	19–21
West Pearl:					
Pearl River, La.	13	([2])	([1])	15.7	20
GREAT LAKES DRAINAGE.					
Sandusky:					
Upper Sandusky, Ohio	13	12	12	13.3	12
MISSISSIPPI DRAINAGE.					
Monongahela:					
Lock 15, Hoult, W. Va.	22	4	4	24.5	4
Lock 7, Martin, Pa.	30	3	4	32.7	3
Lock 4, Pa.	31	4	4	36.4	4
Youghiogheny:					
Confluence, Pa.	10	3	3	10.0	3
Ohio:					
Pittsburgh, Pa.	22	4	4	27.4	4
Lock 2, Coraopolis, Pa.	26	4	4	26.0	4
Dam No. 6, Beaver, Pa.	30	4	4	35.0	4
Marietta, Ohio	33	4	6	34.9	5
MISSISSIPPI DRAINAGE—continued.					
Ohio—Continued.	*Feet.*			*Feet.*	
Parkersburg, W. Va.	36	4	6	37.0	5
Point Pleasant, W. Va.	40	3	7	45.9	5
Dam 28, Near Huntington, W. Va.	50	5	5	50.4	5
Dam No. 29, Normal, Ky.	50	4	7	54.7	5
Dam 30, Greenup, Ky.	52	4	7	53.9	5
Portsmouth, Ohio	50	4	7	54.4	5
Maysville, Ky.	50	4	7	53.5	7
Dam 35, Oneonta, Ky.	45	4	8	49.2	6
Cincinnati, Ohio	52	4	8	55.8	6
Dam 39, Florence, Ind.	45	5	8	47.4	8
Madison, Ind.	46	5	9	48.9	7
Louisville, Ky. (upper gage)	28	5	10	32.9	8
Louisville, Ky. (lower gage)	53	4	12	62.5	8
Cloverport, Ky.	40	5	14	47.1	8
Evansville, Ind.	35	2	26	43.5	10–11
Henderson, Ky.	33	3	26	41.5	11–12
Dam 48, Cypress, Ind.	42	3	26	50.4	11–12
Mount Vernon, Ind.	35	2	36	42.7	12
Shawneetown, Ill.	35	([2])	27	44.2	14
Shenango:					
Sharon, Pa.	9	12	13	11.1	12
Tuscarawas:					
Gnadenhutten, Ohio	10	17	19	13.1	18
Coshocton, Ohio	8	12	14	11.0	12
Walhonding:					
Walhonding, Ohio	8	11	12	13.0	11
Scioto:					
Larue, Ohio	11	11	12	13.2	11
Circleville, Ohio	10	12	13	13.8	13
Chillicothe, Ohio	16	13	13	17.2	13
Licking:					
Farmers, Ky.	25	3	4	26.2	3
Kentucky:					
Beattyville, Ky.	30	4	4	31.4	4
High Bridge, Ky.	30	4	5	34.6	4
Frankfort, Ky.	31	4	6	36.3	4
Green:					
Lock 6, Brownsville, Ky.	30	4	8	35.7	6
Lock 4, Woodbury, Ky.	33	3	10	44.2	7
Lock 2, Rumsey, Ky.	34	4	23	40.6	12–13
Wabash:					
Lafayette, Ind.	11	12	13	12.0	13
		30	([1])	[3] 20.0	31
Mount Carmel, Ill.	16	([2])	3	....	....
		17	18	16.2	18
White (East Fork):					
Seymour, Ind.	10	11	11	10.0	11
White (West Fork):					
Edwardsport, Ind.	14	12	17	16.8	14
Cumberland:					
Burnside, Ky.	50	3	4	54.2	3
Celina, Tenn.	45	5	7	46.4	6
Carthage, Tenn.	40	4	8	45.1	5
Nashville, Tenn.	40	4	11	44.0	8
Clarksville, Tenn.	46	5	13	48.4	12
Lock F, Eddyville, Ky.	57	10	15	58.9	13
Tennessee:					
Riverton, Ala.	33	4	8	35.7	6
French Broad:					
Penrose, N. C.	13	11	12	14.2	11
Asheville, N. C.	4	16	17	4.3	16
Big Pigeon:					
Newport, Tenn.	6	11	11	6.5	11
Holston (North Fork):					
Mendota, Va.	8	1	1	9.3	1
Mississippi:					
New Madrid, Mo.	34	14	18	34.2	15–17
St. Francis:					
Marked Tree, Ark.	17	([2])	5	17.4	1–3
Cache:					
Patterson, Ark.	9	([2])	2	10.5	Dec. 23–25
Yazoo:					
Yazoo City, Miss.	25	24	([1])	25.8	31
Tallahatchie:					
Swan Lake, Miss.	25	7	([1])	28.4	18–20
Red:					
Alexandria, La.	36	([2])	5	36.9	Dec. 31–Jan. 3
Sulphur:					
Ringo Crossing, Tex.	20	25	26	22.0	25
Finley, Tex.	24	30	([1])	24.4	31
Cypress:					
Jefferson, Tex.	18	([2])	2	18.5	Dec. 31–Jan. 1
WEST GULF DRAINAGE.					
Sabine:					
Logansport, La.	25	([2])	4	28.2	Dec. 26–27
Trinity:					
Liberty, Tex.	25	([2])	10	....	....
		28	30	25.5	29
COLORADO DRAINAGE.					
Gila:					
Kelvin, Ariz.	5	([2])	5	6.4	Dec. 29

[1] Continued at end of month. [2] Continued from last month. [3] Ice gorge.

MEAN LAKE LEVELS DURING JANUARY, 1924.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., Feb. 5, 1924.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Mean level during January, 1924				
Above mean sea level at New York	601.56	578.58	571.29	244.77
Above or below—				
Mean stage of December, 1923	−0.17	−0.22	+0.04	+0.30
Mean stage of January, 1923	−0.22	−0.44	+0.13	+0.27
Average stage for January, last 10 years	−0.55	−1.32	−0.35	−0.51
Highest recorded January stage	−1.22	−4.09	−2.26	−2.83
Lowest recorded January stage	+0.68	−0.44	+0.33	+0.97
Average relation of the January level to—				
December level		(2)	−0.1	(2)
February level		(2)	+0.2	(2)

[1] Lake St. Clair's level: In January, 1924, 574.08 feet. [2] Practically no difference.

EFFECT OF WEATHER ON CROPS AND OUTDOOR OPERATIONS, JANUARY, 1924.

By J. B. KINCER.

January was generally cold, stormy, and disagreeable in nearly all sections of the country, and mostly unfavorable for outdoor operations. Very little field work was accomplished in the Southern States because of frequent rains and cold weather, although considerable preparation of soil was accomplished in much of Texas and in Florida. The conditions were favorable for lumbering in the Central-Northern and Northeastern States, and good weather for ice harvest prevailed generally in the North.

Winter wheat fields were fairly well protected by snow during much of the month in the northern portions of Ohio, Indiana, and Illinois, but the weather was hard on wheat and other grains in the immediate Ohio Valley, especially Kentucky and in Tennessee, while winter oats were severely damaged by freezing in the Southeast. There was considerable complaint of wheat lifting as a result of alternate freezing and thawing in immediate Ohio Valley localities, and late-sown fields were badly damaged, though the early-sown, well-rooted grain fared better.

Wheat was mainly frozen to the ground in Kansas, but came through the cold weather with apparently little damage, largely because of the splendid root system established through favorable growing conditions in the fall and early winter months. Wheat apparently was not damaged appreciably in other western portions of the belt, though there was complaint of alternate thawing and freezing during a part of the month in the extreme lower Great Plains.

Severely cold weather overspread the Southeastern States early in the month, bringing temperatures slightly below zero in the northern parts of the east Gulf States, with 14° above zero extending to the east Gulf coast. This freeze destroyed tender truck crops in the lower Mississippi Valley and damaged hardy varieties. Cabbage was almost completely destroyed in southern Alabama, while other truck crops were nearly all killed in southern Georgia and extreme northern Florida. There was much damage also in the South Atlantic States, especially in South Carolina. Truck fared better in the west Gulf districts where no widespread, serious damage occurred.

Most of the month was cold, stormy, and unfavorable for stock in the Great Plains and Rocky Mountain districts. The snow-covered range in the Mountain States necessitated much feeding. The latter part of the month was warmer, however, and more favorable for stock interests in the great western grazing sections. Pastures were generally poor in the Southeastern States because of unfavorable fall and winter weather, and considerable feeding of livestock was necessary, with feed scarce in some sections. Pastures and ranges were very poor in California because of deficient moisture, and feeding was general, with heavy losses of range cattle and sheep.

During the first part of the month there was considerable damage by frost to citrus fruit in the San Joaquin Valley of California, and some harm was reported from southern California, while at the same time satsumas were defoliated in east Gulf districts, the younger trees especially being injured. There was no damage in the main citrus belt of Florida, however, where the month on the whole was favorable. The premature development of fruit buds in the South Atlantic Coast States was checked by the cold weather, and the cold apparently did little harm to fruits in southern Texas, while citrus in Arizona escaped injury. Peach buds were reported in good condition in Georgia, but there was considerable complaint of damage in the Lake districts of Ohio and in Indiana and Illinois during the first half of the month.

CLIMATOLOGICAL TABLES.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 176 Weather Bureau stations making simultaneous observations at 8 a.m. and 8 p. m. daily, 75th meridian time, and for about 37 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives, for about 35 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, and depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January, 1902, pages 13–16.

Chart I.—*Tracks of centers* of ANTICYCLONES; and

Chart II.—*Tracks of centers* of CYCLONES. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th meridian time. Within each circle is also given (Chart I) the last three figures of the highest barometric reading, or (Chart II) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea level and standard gravity. The inset map in Chart I shows the departure of monthly mean pressure from normal and the inset in Chart II shows the change in mean pressure from the preceding month.

Chart III.—*Temperature departures.* This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart IV.—*Total precipitation.* The scales of shading with appropriate lines show the distribution of the

monthly precipitation. The inset on this chart shows the departure of the monthly totals from the corresponding normals.

Chart V.—*Percentage of clear sky between sunrise and sunset.* The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VI.—*Isobars at sea level, average surface temperatures, and prevailing wind directions.* The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The sea level temperatures are now omitted and average surface temperatures substituted. The isotherms can not be drawn in such detail as might be desired, for data from only the regular Weather Bureau stations are used.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations determine the prevailing direction from the daily or twice-daily observations only.

Chart VII.—*Total snowfall.* This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. This chart is published only when the snowfall is sufficiently extensive to justify its preparation.

Charts VIII, IX, etc.—*North Atlantic weather maps of particular days.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January, 1924.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	41.8	−4.7	3 stations	75	[1] 1	Valley Head	−2	5	6.67	+1.73	Pushmataha	9.32	Calera	3.99
Arizona	40.5	−2.0	Yuma Citrus Station	81	[1] 30	Williams	−16	1	0.09	−1.32	Henry's Camp	0.64	45 stations	0.00
Arkansas	36.1	−4.8	Rison	79	31	4 stations	−6	5	3.19	−1.04	Warren	6.50	Searcy	1.05
California	45.3	−0.5	Barrett Dam	86	30	Helm Creek	−33	2	1.97	−3.52	Wrights	7.02	8 stations	0.00
Colorado	20.1	−4.4	Las Animas	74	31	4 stations	−40	[1] 5	0.38	−0.50	Steamboat Springs	2.07	2 stations	0.00
Florida	59.9	+0.6	2 stations	88	[1] 1	....do	12	[1] 6	4.12	+1.25	Cottage Hill	8.79	St. Leo	1.66
Georgia	43.3	−3.5	St. George	81	3	Clayton	−9	6	5.39	+1.45	Clayton	11.53	Savannah	2.78
Idaho	19.8	−3.7	Burley	57	31	3 stations	−33	4	1.04	−1.18	Priest River Ex. Station.	4.08	American Falls	T.
Illinois	21.9	−4.6	Carbondale	62	[1] 30	Freeport	−25	5	1.78	−0.66	Golconda	3.16	Roberts	0.70
Indiana	23.8	−4.8	Hickory Hill	60	29	2 stations	−20	21	2.97	−0.22	Jeffersonville	4.76	Howe	1.20
Iowa	13.9	−4.0	Keokuk	59	8	Washta	−36	5	0.89	−0.16	Waverly	2.47	Storm Lake	0.06
Kansas	26.2	−3.6	2 stations	67	[1] 8	Centralia	−27	5	0.39	−0.26	Walnut	1.61	11 stations	T.
Kentucky	31.3	−4.2	....do	66	[1] 1	2 stations	−8	[1] 5	5.02	+0.64	Glasgow	6.96	Sergent	3.36
Louisiana	46.7	−4.5	....do	80	[1] 2	Kelly (near)	8	6	6.39	+1.84	Baton Rouge	8.98	Paradis	3.25
Maryland-Delaware	33.7	+1.1	3 stations	67	11	Frostburg, Md	−10	6	4.06	+0.78	Woodstock, Md	6.10	Solomons, Md	2.45
Michigan	15.8	−3.7	Harbor Beach	55	5	Bergland	−30	21	2.26	+0.36	Grand Marais	5.73	Sidnaw	1.04
Minnesota	3.0	−5.1	Canby	50	29	Itasca State Park	−47	6	0.37	−0.40	....do	1.35	Alexandria	0.00
Mississippi	42.2	−5.1	Shubuta	78	1	2 stations	2	6	6.56	+1.59	Magnolia	10.98	Hernando	3.84
Missouri	24.9	−5.5	2 stations	68	31	Conception	−25	5	1.54	−0.49	Caruthersville	4.44	Maryville	0.23
Montana	15.6	−2.9	Hays	63	31	Kinread	−53	1	0.68	−0.31	Trout Creek	2.97	Savage	0.00
Nebraska	17.4	−4.6	McCook	68	30	Gordon	−37	5	0.34	−0.22	Tecumseh	1.70	1 station	0.00
Nevada	25.4	−5.8	Pahrump	75	[1] 26	Millett	−31	6	0.34	−0.76	Austin	1.10	3 stations	0.00
New England	23.6	+2.8	Plymouth, Mass	68	12	2 stations	−34	28	3.72	+0.35	Kingston, R. I	6.40	Rutland, Mass	1.09
New Jersey	32.2	+2.2	Little Falls	65	11	Culvers Lake	−6	27	4.48	+0.83	Charlotteburg	5.69	Sussex	2.88
New Mexico	30.6	−3.2	Pearl	74	31	Dulce	−24	5	0.21	−0.40	Lake Alice	1.43	15 stations	0.00
New York	24.9	+2.0	Ballston Lake	62	11	2 stations	−40	27	3.26	+0.30	Lowville	7.97	Chazy	0.65
North Carolina	39.6	−1.6	Greenville	75	9	Banners Elk	−12	6	4.75	+1.01	Highlands	8.67	Parker	2.04
North Dakota	2.6	−2.3	Berthold Agency	61	31	Dunseith	−42	[1] 1	0.23	−0.31	Hannah	0.96	3 stations	0.00
Ohio	25.0	−3.3	Clarington	64	1	Paulding	−16	22	3.73	+0.63	Bucyrus	5.87	Bowling Green	1.38
Oklahoma	34.7	−4.0	Altus	76	30	Goodwell	−10	17	0.72	−0.65	Antlers	3.80	4 stations	0.00
Oregon	31.3	−1.4	2 stations	69	[1] 30	Madras	−24	1	2.46	−2.14	Government Camp	9.73	Silver Lake	0.12
Pennsylvania	28.1	+0.3	New Castle	65	1	Montrose	−13	28	4.34	+1.05	Phoenixville	6.29	Lawrenceville	1.70
South Carolina	43.3	−2.3	2 stations	76	3	Landrum	1	6	4.34	+0.88	Walhalla	6.20	Pinopolis	2.94
South Dakota	10.7	−4.6	Rapid City	59	31	La Delle	−41	5	0.21	−0.31	Harveys Ranch	1.10	10 stations	T.
Tennessee	34.2	−4.8	Sevierville	71	10	Rugby	−13	6	5.87	+0.92	Lynnville	8.82	Kenton	3.92
Texas	43.5	−4.9	2 stations	86	[1] 13	Dalhart	−5	1	1.73	−0.02	Willis	7.75	18 stations	0.00
Utah	20.1	−5.3	Leeds	68	31	Panguitch	−30	5	0.47	−0.84	Silver Lake	2.49	McCornick	0.00
Virginia	35.3	−0.7	Runnymede	75	11	Burkes Garden	−12	6	3.93	+0.62	Mendota	6.78	Norfolk	1.96
Washington	29.6	−1.4	Kennewick	69	31	Snyders Ranch	−33	1	3.50	−1.15	Forks	18.47	Attalia	0.07
West Virginia	30.1	−2.7	Clarksburg	70	12	Cheat Bridge	−15	6	4.62	+0.57	Cheat Bridge	7.14	White Sulphur Springs.	0.62
Wisconsin	6.7	−7.2	Kilbourn	48	30	Hatfield	−44	4	0.81	−0.43	Beloit	2.09	Grantsburg	0.08
Wyoming	15.1	−4.2	3 stations	57	[1] 30	4 stations	−42	[1] 1	0.52	−0.33	Bedford	1.38	3 stations	T.

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1924.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F.	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
New England.							27.4	+3.0										72	3.62	+0.1										5.8		
Eastport	76	67	85	29.96	30.04	+.04	22.4	+2.0	50	11	32	−19	27	13	54	20	14	71	3.62	−0.2	17	9,516	w.	47	se.	17	10	6	15	6.2	15.4	0.3
Greenville, Me.	1,070	6		28.82	30.04		13.9		41	30	25	−26	27	2	49				2.55		10		se.				13	15	3		18.5	17.0
Portland, Me.	103	82	117	29.97	30.10	+.05	24.3	+1.9	48	11	34	−18	27	15	48	22	16	70	4.50	+0.7	11	7,765	sw.	39	se.	16	17	6	8	4.4	25.5	5.2
Concord	288	70	79	29.76	30.09	+.04	23.1	+1.5	51	11	34	−18	27	13	40				3.82	+0.5	8	4,439	w.	36	w.	21	11	8	12	5.5	24.1	5.5
Burlington	404	11	48	29.62	30.09	+.04	20.9	+4.6	51	11	30	−19	28	11	40				2.39	+0.6	12	10,424	s.	44	nw.	21	2	7	22	7.9	12.4	T.
Northfield	876	12	60	29.10	30.09	+.04	19.5	+4.4	53	11	31	−28	28	8	42	17	13	80	2.24	−0.2	15	6,743	s.	35	sw.	26	3	9	19	7.5	21.7	3.8
Boston	125	115	188	29.97	30.11	+.06	31.9	+4.0	61	11	40	−6	27	23	37	27	19	61	3.27	−0.6	8	9,171	w.	50	w.	21	12	10	9	5.0	8.5	0.0
Nantucket	12	14	90	30.10	30.11	+.07	34.0	+1.9	57	11	41	5	27	27	35	31	28	80	3.28	−0.1	8	14,526	sw.	57	se.	16	6	12	13	6.4	0.3	0.0
Block Island	26	11	46	30.09	30.12	+.05	33.2	+2.2	55	11	40	3	27	26	36	31	26	75	4.36	+0.5	10	18,201	nw.	62	nw.	21	11	4	16	6.0	0.4	0.0
Providence	160	215	251	29.95	30.13	+.07	30.8	+3.6	59	11	39	−2	27	22	30	27	21	70	4.13	−0.2	9	11,815	nw.	72	nw.	21	13	11	7	4.7	5.0	0.0
Hartford	159	122	140	29.97	30.14	+.07	29.8	+4.3	59	11	39	−2	27	21	30				3.70	−0.1	8		nw.				12	10	9	5.2	4.0	0.0
New Haven	106	74	153	30.03	30.16	+.08	31.2	+3.0	56	11	39	0	27	23	28	28	22	70	4.50	+0.6	7	8,279	sw.	52	s.	11	13	8	10	4.6	2.9	0.0
Middle Atlantic States.							33.5	+1.6										70	3.52	+0.3										5.3		
Albany	97	102	115	30.03	30.14	+.07	27.0	+3.9	57	11	35	−11	27	19	33	24	19	72	2.12	−0.5	10	6,586	s.	32	s.	11	11	8	12	5.5	5.3	T.
Binghamton	871	10	84	29.14	30.10	+.02	27.8	+4.7	56	11	36	0	22	19	32				2.30	+0.3	11	6,387	nw.	34	nw.	25	2	10	19	7.6	2.6	0.0
New York	314	414	454	29.82	30.17	+.07	32.5	+1.6	57	16	41	4	22	24	25	28	21	63	3.56	−0.2	6	16,924	nw.	74	nw.	25	10	9	12	5.5	2.5	0.0
Harrisburg	374	94	104	29.79	30.21	+.11	30.6	+1.6	57	11	38	4	21	23	26	26	20	67	5.05	+2.2	6	5,527	nw.	33	nw.	25	9	6	16	6.0	2.5	T.
Philadelphia	114	123	190	30.07	30.21	+.10	34.6	+2.0	61	11	43	6	22	27	26	30	22	62	4.45	+1.0	6	8,618	n.	42	sw.	11	12	7	12	5.2	0.5	0.0
Reading	325	81	98	29.83	30.20		31.3		63	11	39	4	22	23	27	28	24	73	4.62	+1.1	7	6,514	nw.	37	e.	25	12	10	9	5.3	2.0	0.0
Scranton	805	111	119	29.27	30.16	+.07	29.0	+3.5	58	11	38	0	27	20	27	26	21	76	3.73	+0.9	8	7,127	sw.	42	sw.	1	6	14	11	6.3	2.9	T.
Atlantic City	52	37	172	30.14	30.20	+.09	35.2	+2.7	60	1	43	6	22	27	31	31	26	70	3.28	−0.1	8	15,218	nw.	80	se.	16	14	6	11	4.6	T.	0.0
Cape May	17	13	49	30.22	30.24	+.12	35.6	+1.5	58	1	43	9	22	28	26	32	27	75	3.33	0.0	11	8,240	nw.	68	se.	16	14	4	13	5.0	T.	0.0
Sandy Hook	22	10	55	30.15	30.17		33.2		56	11	40	6	22	26	24	30	24	72	5.13		7	14,604	w.	72	s.	11	12	9	10	5.0	T.	0.0
Trenton	190	159	183	29.97	30.19		32.6		63	11	41	4	22	24	29	29	22	67	4.71	+1.5	6	10,774	nw.	62	nw.	25	13	10	8	5.0	0.6	0.0
Baltimore	123	100	113	30.07	30.21	+.09	34.8	+1.0	60	11	43	7	22	26	28	30	23	67	4.33	+1.1	6	4,601	nw.	32	se.	16	11	9	11	5.2	0.4	0.0
Washington	112	62	85	30.09	30.22	+.09	35.0	+1.6	63	11	44	6	22	26	28	29	22	65	3.21	−0.2	6	5,564	nw.	44	nw.	5	12	9	10	4.9	0.5	0.0
Cape Henry	18	8	54	30.19	30.21		41.9		69	11	50	14	6	34	29	38	34	80	3.38	0.0	10	11,499	sw.	48	n.	1	14	4	13	5.1	0.0	0.0
Lynchburg	681	153	188	29.45	30.22	+.09	36.2	−1.3	67	11	48	3	6	25	40	30	24	69	3.37	−0.4	7	5,599	w.	46	w.	11	15	7	9	4.4	0.8	0.0
Norfolk	91	170	205	30.13	30.23	+.10	42.2	+1.6	68	1	51	10	6	33	31	37	31	71	1.96	−1.4	9	10,898	n.	56	s.	16	14	4	13	5.1	T.	0.0
Richmond	144	11	52	30.06	30.23	+.10	35.0	+0.1	67	11	49	8	22	27	35	32	25	68	2.98	0.0	7	6,861	ne.	38	sw.	11	15	10	6	4.0	T.	0.0
Wytheville	2,304	49	55	27.76	30.26	+.12	30.6	−2.4	58	11	41	−5	6	21	35	26	21	73	3.49	−0.8	7	5,692	w.	36	w.	11	13	5	13	5.2	T	0.0
South Atlantic States.							44.3	−1.3										75	3.79	+0.2										5.4		
Asheville	2,255	70	84	27.81	30.28	+.13	33.6	−1.8	60	10	44	−5	6	23	34	28	23	73	3.74	+0.9	8	7,985	nw.	46	s.	10	14	9	8	4.2	T.	0.0
Charlotte	779	55	62	29.36	30.22	+.07	40.0	−1.2	67	11	50	5	6	30	30	34	28	67	3.98	−0.3	9	3,969	n.	25	w.	11	14	2	15	5.2	0.0	0.0
Hatteras	11	11	50	30.20	30.21	+.07	46.4	−0.7	69	3	53	17	6	39	24	44	41	83	5.40	+0.5	13	11,659	n.	46	nw.	6	12	6	13	5.7	0.0	0.0
Manteo	12	5	42				44.2		68	3		14	6		32				2.54		9		ne.				16	5	10		0.0	0.0
Raleigh	376	103	110	29.82	30.24	+.11	40.8	−0.3	68	1	51	7	6	30	31	35	30	70	3.84	+0.3	8	6,181	n.	41	sw.	16	13	5	13	5.2	T.	0.0
Wilmington	78	81	91	30.15	30.24	+.10	47.2	+0.7	71	10	57	12	6	37	30	42	38	78	2.21	−1.3	12	5,519	n.	38	s.	16	15	2	14	5.1	0.0	0.0
Charleston	48	11	92	30.17	30.22	+.07	48.9	−1.0	71	3	57	17	6	41	26	44	40	76	3.24	−0.2	10	7,760	ne.	40	sw.	16	9	4	18	6.5	0.0	0.0
Columbia, S. C.	351	41	57	29.85	30.25	+.10	43.6	−2.4	69	1	54	10	6	33	35	38	33	73	3.37	+0.1	10	4,903	ne.	32	s.	16	13	5	13	5.2	0.0	0.0
Due West	711	10	55	29.46	30.26		39.4		66	10	50	7	6	29	35				5.03		9	6,640	ne.	36	e.	24	11	7	13	5.2	0.0	0.0
Greenville, S. C.	1,039	113	122	29.08	30.21		39.2	−1.1	65	11	49	5	6	30	31	33	27	68	5.09		9	6,022	ne.	35	nw.	25	15	5	11	4.5	0.0	0.0
Augusta	180	62	77	30.03	30.23	+.07	44.4	−2.6	72	10	55	12	6	34	38	39	35	79	4.26	+0.1	10	4,083	nw.	36	s.	16	14	4	13	5.2	0.0	0.0
Savannah	65	150	194	30.15	30.22	+.07	49.5	−1.9	76	3	59	20	6	40	32	44	39	76	2.78	−0.4	10	8,948	nw.	44	s.	16	13	4	14	5.7	0.0	0.0
Jacksonville	43	209	245	30.15	30.20	+.05	53.7	−1.7	78	3	62	21	7	46	29	49	45	78	5.09	+2.0	11	9,623	ne.	46	sw.	16	6	4	21	7.2	0.0	0.0
Florida Peninsula.							67.3	+1.6										84	2.58	+0.1										7.7		
Key West	22	10	64	30.08	30.10	.00	71.2	+1.7	83	3	76	57	6	66	21	67	66	88	3.23	+1.2	13	8,603	ne.	33	n.	25	4	9	18	7.1	0.0	0.0
Miami	25	71	79	30.11	30.14		69.5	+2.2	80	25	75	50	6	64	20	66	64	84	2.80	+0.1	15	6,949	e.	29	e.	9	3	3	25	8.2	0.0	0.0
Sand Key	23	39	72	30.08	30.12	+.02	70.5		78	3	74	57	6	67	15	68	66	87	3.02		15	13,616	ne.	54	n.	25	2	11	18	7.4	0.0	0.0
Tampa	35	79	87	30.13	30.17	+.05	61.1	+1.0	81	19	69	34	6	53	28	56	52	79	1.72	−1.1	13	5,176	ne.	26	nw.	20	1	8	22	8.1	0.0	0.0
East Gulf States.							43.9	−4.3										72	6.25	+1.2										5.6		
Atlanta	1,174	190	216	28.96	30.23	+.08	38.2	−4.4	64	10	48	0	6	29	28	34	29	73	4.54	−0.8	11	10,315	nw.	50	nw.	5	12	4	15	5.5	0.0	0.0
Macon	370	78	87	29.84	30.24	+.08	42.7	−4.1	68	10	54	7	6	32	37	37	31	71	5.17	0.0	8	5,104	nw.	29	nw.	5	13	3	15	5.7	T.	0.0
Thomasville	273	49	58	29.91	30.22	+.06	49.4	−1.6	74	3	59	14	6	39	30	44	39	72	6.50	+2.4	12	3,764	ne.	25	sw.	16	7	6	18	7.0	0.0	0.0
Apalachicola	36	42	49	30.16	30.20		50.9		72	3	58	19	6	44	28	47	42	77	4.52		13	7,406	n.	38	nw.	16	9	6	16	6.5	0.0	0.0
Pensacola	56	149	185	30.16	30.22	+.08	48.6	−3.9	69	30	57	14	6	40	30	43	38	71	7.82	+3.8	9	10,735	ne.	65	nw.	16	10	4	17	6.4	0.0	0.0
Anniston	741	9	57	29.46	30.28	+.12	38.2	−4.0	64	30	49	2	6	27	35				5.83	+0.5	9	5,152	nw.	27	se.	2	14	9	8	4.8	0.0	0.0
Birmingham	700	11	48	29.48	30.28	+.12	40.0	−5.1	66	31	50	4	6	30	32	34	28	67	5.42	+0.1	11	5,853	n.	35	se.	10	16	6	9	4.4	0.0	0.0
Mobile	57	125	161	30.17	30.23	+.08	47.4	−4.8	73	31	58	14	6	37	29	43	38	74	8.21	+3.4	9	8,229	n.	40	n.	5	6	12	13	5.9	0.0	0.0
Montgomery	223	100	112	30.01	30.27	+.11	43.2	−5.0	70	10	53	8	6	33	33	38	32	69	6.42	+1.3	9	5,317	n.	35	w.	16	13	4	14	5.5	T.	0.0
Corinth	469	6					38.0		68	31	49	3	6	27	35				6.98		11		n.				9	15	7		T.	0.0
Meridian	375	85	93	29.84	30.26	+.10	42.0	−5.0	70	2	54	8	6	31	34	37	31	70	6.46	+0.9	12	4,614	ne.	30	w.	10	13	7	11	5.1	0.0	0.0
Vicksburg	247	65	73	29.99	30.28	+.13	43.5	−4.7	70	31	53	11	6	34	30	38	32	71	6.18	+0.5	10	5,546	se.	31	nw.	10	14	9	8	4.7	0.0	0.0
New Orleans	53	76	84	30.17	30.23	+.10	49.4	−4.8	75	2	58	19	6	41	31	44	39	72	6.17	+1.5	8	5,841	ne.	30	nw.	10	11	6	14	5.7	0.0	0.0
West Gulf States.							43.0	−3.6										75	2.74	−0.3										5.4		
Shreveport	249	77	93	29.98	30.27	+.13	42.8	−3.4	74	31	51	15	6	34	30	37	31	69	4.24	−0.2	9	4,926	se.	24	w.	10	16	3	12	4.5	T.	0.0
Bentonville	1,303	11	44				30.6	−3.5	62	30	40	−6	5	22	34				1.49		13	4,850	s.	20	s.	9	15	4	12		4.3	0.0
Fort Smith	457	79	94	29.73	30.24	+.10	35.2	−4.3	65	31	44	5	5	26	31	30	25	71	2.02	−0.5	9	6,680	e.	33	e.	15	14	6	11	5.0	0.5	0.0
Little Rock	357	136	144	29.86	30.26	+.11	36.9	−4.5	69	31	46	8	5	28	31	33	28	74	3.56	−1.2	8	6,465	s.	35	n.	20	16	1	14	4.9	T.	0.0
Brownsville	57	53	61	30.11	30.17		55.2		76	31	62	35	5	48	27	50	47	82	3.42		14	6,292	n.	32	s.	9	3	8	20	7.6	T.	0.0
Corpus Christi	20	11	73	30.20	30.22	+.12	50.8	−2.7	72	9	58	31	7	44	30	47	44	79	1.14	−1.1	14	8,256	n.	38	n.	20	5	10	16	7.0	0.0	0.0
Dallas	512	109	117	29.68	30.25		41.4		72	31	51	17	6	32	36				1.14		6	6,276	s.	36	nw.	10	14	10	7	4.2	0.0	0.0
Fort Worth	670	106	114	29.49	30.23	+.11	41.4	−2.9	73	30	52	15	6	31	33	36	30	71	0.89	0.0	5	7,267	s.	33	w.	9	17	5	9	4.1	0.0	0.0
Galveston	54	106	114	30.17	30.23	+.10	50.4	−3.4	71	31	56	26	6	44	26	47	44	83	5.87	+2.2	6	9,262	n.	40	nw.	20	8	14	9	5.1	0.0	0.0
Groesbeck	461	11	56	29.73	30.23		43.0		74	31	52	18	6	34	34				2.42		8	7,439	n.	36	se.	9	12	8	11	5.1	0.0	0.0
Houston	138	111	121	30.07	30.23		49.4	−3.5	75	31	58	22	6	40	28				4.87		8	6,289	n.	28	n.	20	9	10	12	5.7	T.	0.0
Palestine	510	64	72	29.70	30.25	+.13	43.4	−4.8	73	31	53	16	6	34	33	39	34	75	3.91	0.0	8	6,021	n.	28	s.	9	12	11	8	5.1	0.0	0.0
Port Arthur	34	58	66	30.18	30.22		48.4		74	31	56	20	6	41	26	44	40	79	6.56		8	7,159	e.	38	nw.	10	8	12	11	5.9	0.0	0.0
San Antonio	693	119	132	29.47	30.22	+.12	47.4	−3.7	77	31	57	24	6	38	36	42	36	70	0.97	−0.7	8	5,589	ne.	34	nw.	10	11	6	14	5.5	0.0	0.0
Taylor	583	55	63	29.63	30.26	+.15	44.2	−3.3	77	31	54	18	6	34	41				2.05	−0.8	8	5,697	n.	32	nw.	20	10	5	16	5.7	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1924*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with 0.01 inch or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
Ohio Valley and Tennessee.	Ft.	Ft.	Ft.	In.	In.	In.	° F. 29.8	° F. −3.8	° F		° F.	° F.		° F.	° F.	° F.	° F.	% 72	In. 4.40	In. +0.6		Miles.								0–10 5.8	In.	In.
Chattanooga	762	189	213	29.44	30.29	+.13	35.5	−5.7	60	31	45	−1	6	26	32	30	23	63	6.24	+0.7	10	5,982	nw.	42	sw.	16	10	12	9	5.0	T.	0.0
Knoxville	996	102	111	29.16	30.25	+.10	34.8	−4.0	68	10	45	−2	6	25	33	30	25	72	4.24	−0.7	9	4,056	sw.	29	sw.	11	11	9	11	5.0	T.	0.0
Memphis	399	76	97	29.82	30.27	+.11	36.4	−4.5	63	31	44	7	5	29	28	32	26	68	6.15	+0.9	9	6,051	se.	32	nw.	4	18	3	10	4.0	0.6	0.0
Nashville	546	168	191	29.68	30.29	+.13	33.4	−5.2	60	31	43	−1	6	24	29	29	24	72	5.40	+0.6	10	7,176	nw.	40	w.	10	13	7	11	4.9	0.7	0.0
Lexington	989	193	230	29.15	30.27	+.14	29.5	−3.4	56	29	38	−6	6	21	27	....	....	....	5.00	+1.2	11	11,375	sw.	42	w.	11	10	8	13	5.6	0.7	0.0
Louisville	525	219	255	29.66	30.28	+.14	29.0	−5.4	56	9	38	−7	5	20	31	26	19	66	4.65	+0.8	11	9,175	s.	38	nw.	25	9	10	12	5.6	1.0	0.0
Evansville	431	139	175	29.78	30.27	+.13	28.9	−4.6	55	9	37	−7	5	21	31	26	20	69	3.16	−0.5	11	8,922	sw.	38	sw.	22	10	10	11	5.5	1.1	0.0
Indianapolis	822	194	230	29.30	30.23	+.11	23.5	−4.9	50	9	32	−13	5	15	33	22	18	77	3.13	+0.3	15	9,816	s.	44	w.	25	11	6	14	5.7	5.1	0.0
Royal Center	736	11	55	29.36	30.20	......	19.0	......	51	9	28	−18	21	10	37	....	....	....	2.06	......	11	8,752	w.	37	w.	25	11	4	16	6.0	7.0	T.
Terre Haute	575	96	129	29.59	30.24	......	23.6	......	50	9	32	−13	5	15	35	22	17	75	2.69	......	12	8,019	s.	32	nw.	25	11	7	13	5.5	4.0	0.0
Cincinnati	628	11	51	29.54	30.25	+.13	26.8	−3.5	54	9	35	−8	5	18	33	....	22	66	4.09	+0.7	15	6,725	sw.	32	sw.	11	10	8	13	5.7	0.9	0.0
Columbus	824	179	222	29.30	30.22	+.11	26.0	−2.6	52	9	34	−8	6	18	32	23	19	76	3.95	+1.0	12	7,922	w.	41	nw.	25	10	4	17	6.4	2.8	0.0
Dayton	899	137	173	29.22	30.22	......	25.3	−3.6	50	9	33	−8	5	18	34	23	18	74	3.71	+0.7	13	8,750	sw.	46	nw.	25	13	5	13	5.5	3.0	0.0
Elkins	1,947	59	67	28.08	30.25	+.13	28.6	−1.8	61	11	41	−7	6	17	44	24	20	79	3.64	+0.3	9	5,458	w.	34	nw.	25	7	7	17	6.7	2.2	0.0
Parkersburg	638	77	84	29.57	30.25	+.13	30.2	−2.3	59	10	39	−1	6	21	38	26	23	80	4.70	+1.5	11	5,280	sw.	35	nw.	25	7	8	16	6.8	0.3	0.0
Pittsburgh	842	353	410	29.26	30.21	+.10	28.7	−2.0	60	10	37	−3	6	20	39	25	19	70	3.53	+0.7	10	10,545	w.	47	nw.	25	2	6	23	8.4	1.3	0.0
Lower Lake Region.							23.3	−1.2										77	2.81	+0.2										7.6		
Buffalo	767	247	280	29.25	30.12	+.05	24.4	−0.2	52	10	32	−7	21	17	34	22	17	75	2.18	−1.1	19	19,254	w.	76	sw.	23	2	8	21	7.8	9.0	0.0
Canton	448	10	61	29.55	30.05	......	18.0	+1.7	51	11	28	−30	27	8	46	....	....	....	4.12	+1.0	16	10,209	sw.	55	w.	1	5	7	19	7.4	20.5	3.2
Oswego	335	76	91	......	30.10	+.03	25.0	+1.1	55	11	33	−16	27	17	33	....	....	80	2.88	−0.3	21	11,140	s.	44	nw.	21	1	6	24	....	26.7	4.2
Rochester	523	86	102	29.51	30.11	+.04	25.2	+0.6	53	11	33	−4	21	17	34	22	17	70	1.77	−1.4	19	8,997	w.	40	sw.	11	1	6	24	8.2	10.0	T.
Syracuse	597	97	113	29.44	30.11	+.04	25.8	+2.8	56	11	34	−15	27	18	32	....	....	....	2.49	+0.4	18	11,339	w.	49	sw.	23	2	7	22	8.0	12.8	T.
Erie	714	130	166	29.33	30.13	+.05	25.4	−1.4	53	11	33	−5	21	18	37	23	19	75	3.13	+0.1	19	14,195	sw.	50	se.	16	0	7	24	8.7	15.1	0.0
Cleveland	762	190	201	29.31	30.17	+.08	24.0	−2.5	49	10	31	−8	6	17	39	22	18	78	3.38	+0.9	20	12,210	w.	60	w.	25	1	8	22	8.7	13.0	0.0
Sandusky	629	62	70	29.46	30.18	+.09	23.4	−2.9	49	10	31	−10	6	16	42	....	....	....	3.11	+1.0	15	6,873	sw.	37	nw.	25	2	12	17	7.6	10.3	0.0
Toledo	628	208	243	29.46	30.17	+.08	22.6	−3.2	46	11	30	−9	6	15	41	21	17	76	2.59	+0.7	12	12,685	sw.	48	sw.	22	6	9	16	6.8	9.1	0.0
Fort Wayne	856	113	124	29.22	30.19	......	20.8	−6.1	48	9	29	−14	5	12	36	19	16	78	2.49	......	11	8,340	sw.	37	w.	25	9	7	15	6.1	8.1	0.0
Detroit	730	218	258	29.31	30.14	+.06	21.8	−2.6	44	10	29	−9	21	15	41	21	18	84	2.46	+0.5	15	10,098	sw.	52	sw.	6	4	12	15	6.9	10.1	0.0
Upper Lake Region.							13.6	−5.0										84	1.85	−0.2										7.0		
Alpena	609	13	92	29.36	30.06	+.02	14.4	−4.7	40	29	23	−12	21	6	35	14	11	82	1.60	−0.6	11	9,583	sw.	46	nw.	25	4	6	21	7.4	17.3	7.0
Escanaba	612	54	60	29.38	30.09	+.04	9.0	−6.4	36	30	18	−18	17	0	35	7	5	89	1.86	+0.3	16	7,293	sw.	33	nw.	25	11	8	12	5.3	22.9	12.5
Grand Haven	632	54	89	29.40	30.12	+.05	20.5	−3.8	41	9	27	−5	21	14	29	20	17	84	2.38	−0.4	20	11,245	w.	48	w.	25	0	4	27	9.2	24.9	3.4
Grand Rapids	707	70	87	29.32	30.13	+.07	20.3	−3.5	44	9	28	−6	21	13	36	19	15	80	2.00	−0.8	15	5,450	w.	28	w.	25	3	7	21	8.2	18.5	2.0
Houghton	668	62	99	29.29	30.06	+.01	8.2	−6.5	41	29	16	−15	20	1	31	....	....	....	3.53	+1.5	20	8,173	w.	43	w.	25	2	3	26	8.8	39.0	17.4
Lansing	878	11	62	29.14	30.12	......	18.7	−3.3	43	9	28	−13	21	10	35	17	15	83	1.83	−0.3	18	5,538	w.	24	nw.	25	5	10	16	7.1	9.8	T.
Ludington	637	60	66	29.36	30.09	......	19.0	......	40	8	25	−8	20	13	29	18	16	86	1.83	......	18	10,880	w.	48	sw.	6	0	11	20	8.3	19.7	0.5
Marquette	734	77	111	29.23	30.08	+.04	10.5	−5.4	50	29	18	−14	20	3	33	9	6	83	3.65	+1.6	23	8,779	w.	33	nw.	5	4	4	23	7.8	36.9	17.9
Port Huron	638	70	120	29.39	30.12	+.06	20.2	−2.1	42	11	28	−9	21	13	37	19	17	84	1.65	−0.2	10	10,168	sw.	40	sw.	6	5	8	18	7.0	9.5	T.
Saginaw	641	69	77	29.38	30.11	......	17.9	−3.8	42	9	26	−11	21	10	37	17	14	85	1.33	−0.9	7	7,239	sw.	38	sw.	6	4	8	19	7.7	7.2	0.2
Sault Sainte Marie	614	11	52	29.31	30.05	+.02	8.2	−5.1	34	29	17	−26	27	−1	32	7	5	87	2.71	+0.5	19	5,780	se.	36	nw.	25	2	5	24	8.5	28.3	22.2
Chicago	823	140	310	29.25	30.18	+.08	19.8	−5.3	48	9	28	−16	5	12	37	18	12	67	1.32	−0.7	9	9,394	w.	35	sw.	22	11	8	12	5.2	5.7	0.0
Green Bay	617	109	144	29.40	30.11	+.05	8.4	−6.2	38	31	18	−23	21	−1	39	7	6	90	0.78	−0.9	8	9,137	w.	37	e.	10	10	13	8	5.4	9.1	3.4
Milwaukee	681	125	139	29.36	30.14	+.06	14.0	−6.6	40	8	22	−19	21	6	38	13	10	82	0.95	−1.1	10	7,903	w.	40	sw.	6	11	9	11	5.2	8.5	0.1
Duluth	1,133	11	47	28.81	30.12	+.03	0.8	−7.1	45	29	10	−31	5	−9	39	0	−2	91	0.25	−0.7	6	10,233	w.	48	nw.	25	14	9	8	4.5	2.3	3.5
North Dakota.							3.0	−1.6										82	0.23	−0.4										5.8		
Moorhead	940	50	58	29.08	30.17	+.03	1.4	−2.4	43	29	12	−35	5	−9	45	1	−4	74	0.16	−0.6	6	6,356	n.	29	s.	5	13	6	12	5.5	1.8	0.1
Bismarck	1,674	8	57	28.31	30.22	+.09	6.2	−1.6	50	30	18	−29	5	−5	49	4	2	83	0.04	−0.5	3	6,356	nw.	34	nw.	25	10	9	12	5.6	0.5	T.
Devils Lake	1,478	11	44	28.45	30.14	+.02	−0.6	−0.9	38	28	10	−32	4	−11	51	−2	−4	87	0.35	−0.2	5	7,364	w.	32	w.	18	12	8	11	5.2	5.1	1.1
Ellendale	1,457	10	56	28.52	30.18	......	5.1	......	50	28	17	−32	5	−7	54	....	....	....	0.07	......	4	9,970	nw.	40	n.	9	11	10	10	5.6	0.7	T.
Grand Forks	835	12	89	......	......	......	−1.9	......	38	29	10	−33	5	−14	45	....	....	....	0.81	......	11	......	w.	33	s.	5	11	8	12	....	9.2	2.3
Williston	1,878	41	48	28.06	30.16	+.05	5.1	−1.4	48	31	16	−28	17	−6	41	4	2	86	0.38	−0.2	7	6,033	w.	34	w.	6	5	5	21	7.2	2.8	0.0
Upper Mississippi Valley.							17.3	−4.6										78	1.16	−0.6										5.0		
Minneapolis	918	102	208	29.08	30.12	......	8.0	......	44	29	17	−28	5	−1	44	....	....	....	0.54	−0.2	6	8,378	nw.	36	nw.	25	12	8	11	4.9	7.7	2.2
St. Paul	837	236	261	29.20	30.17	+.06	7.1	−5.5	40	29	16	−27	5	−2	42	....	....	....	0.97	+0.1	8	8,931	sw.	40	nw.	25	14	5	12	4.9	10.3	1.5
La Crosse	714	11	48	29.35	30.18	+.07	8.3	−7.8	40	29	19	−27	5	−2	39	....	....	....	0.91	−0.2	6	4,008	se.	22	s.	6	16	7	8	4.4	10.3	9.0
Madison	974	70	78	29.05	30.18	+.08	11.4	−5.3	40	29	20	−25	5	2	41	10	5	75	0.56	−1.0	10	7,461	w.	33	sw.	6	10	7	14	5.8	5.8	0.9
Wausau	1,247	4	....	28.72	30.14	......	4.8	......	36	29	14	−25	21	−4	39	....	....	....	0.97	......	7	......	nw.	......	......	......	14	7	10	4.6	11.4	6.5
Charles City	1,015	10	49	29.04	30.19	+.05	8.3	−3.1	41	31	19	−28	5	−2	40	7	5	90	1.18	+0.2	8	4,991	w.	24	nw.	25	15	9	7	4.2	13.2	3.5
Davenport	606	71	79	29.50	30.18	+.09	17.2	−4.6	47	8	26	−21	5	9	39	16	13	82	1.27	−0.3	9	5,745	nw.	27	nw.	25	11	10	10	5.3	8.7	T.
Des Moines	861	84	97	29.24	30.20	+.06	17.0	−3.1	51	30	26	−22	5	8	35	15	12	83	1.02	−0.2	6	5,600	nw.	27	sw.	6	15	7	9	4.8	4.5	T.
Dubuque	700	81	96	29.41	30.21	+.09	13.6	−5.5	44	8	22	−24	5	5	39	12	8	77	0.63	−0.9	8	4,914	nw.	26	nw.	25	10	11	10	5.4	4.3	1.6
Keokuk	614	64	78	29.52	30.23	+.09	21.6	−3.3	59	8	31	−19	5	12	41	15	12	73	1.31	−0.4	9	6,034	sw.	30	sw.	22	10	8	13	5.6	9.0	0.0
Cairo	358	87	93	29.86	30.26	+.10	30.6	−4.3	57	30	38	−4	5	22	33	27	22	71	2.67	−1.2	12	7,103	s.	34	n.	19	10	8	13	5.5	2.0	0.0
Peoria	609	11	45	29.52	30.22	+.10	19.0	−4.1	51	8	28	−20	5	10	38	18	15	84	1.72	−0.5	9	5,488	s.	26	nw.	25	16	4	11	4.6	5.0	0.0
Springfield, Ill.	636	10	91	29.50	30.21	+.08	21.8	−4.7	52	8	30	−16	5	14	33	20	17	83	1.23	−1.0	7	6,845	s.	28	nw.	25	14	4	13	5.0	6.3	T.
Hannibal	534	74	109	29.63	30.23	+.10	23.0	−4.1	58	8	32	−16	5	14	38	....	....	....	1.10	−1.1	10	6,962	sw.	36	sw.	22	12	7	12	5.1	6.0	0.0
St. Louis	568	265	303	29.60	30.23	+.09	26.6	−4.2	61	8	35	−11	5	18	34	24	17	67	1.15	−1.1	13	10,323	s.	37	nw.	25	13	5	13	5.3	3.9	0.0
Missouri Valley.							18.7	−4.0										79	0.62	−0.4										4.7		
Columbia, Mo.	784	11	84	29.36	30.24	+.11	24.0	−5.2	60	8	34	−16	5	14	42	....	....	....	1.22	−1.0	11	6,407	s.	30	nw.	4	13	7	11	5.1	10.3	0.0
Kansas City	963	161	181	29.14	30.22	+.07	25.4	−2.8	59	8	34	−15	5	16	36	22	16	72	1.20	+0.1	9	8,771	s.	33	nw.	4	14	7	10	4.6	6.4	0.0
St. Joseph	967	11	49	29.12	30.21	......	22.0	......	56	30	32	−19	5	13	37	19	16	82	0.66	......	10	6,592	nw.	30	nw.	10	15	8	8	4.4	3.3	0.0
Springfield, Mo.	1,324	98	104	28.77	30.23	+.09	28.4	−5.1	58	8	38	−11	5	19	37	25	22	82	1.50	−1.2	13	8,605	s.	30	w.	10	14	7	10	4.6	3.3	0.0
Iola	984	11	50	29.14	30.24	+.10	27.1	−0.5	62	30	37	−10	5	17	34	....	....	....	0.81	−0.2	8	5,756	s.	23	n.	19	14	6	11	4.9	3.1	0.0
Topeka	987	92	107	......	......	......	24.6	−3.0	60	30	35	−15	5	14	42	....	....	....	0.61	−0.3	6	7,686	s.	35	nw.	10	16	8	7	3.9	5.6	0.0
Drexel	1,299	10	54	28.73	30.20	......	14.4	......	48	29	24	−25	5	4	41	....	....	....	0.37	......	7	8,035	nw.	30	s.	17	14	7	10	5.1	3.9	0.1
Lincoln	1,189	11	84	28.88	30.22	+.07	17.9	−4.9	52	29	28	−19	5	8	38	16	13	83	0.58	0.0	6	6,987	s.	30	n.	24	13	6	12	5.3	5.2	0.0
Omaha	1,105	115	122	28.97	30.22	+.07	17.4	−4.5	51	30	27	−20	5	8	44	15	11	77	0.62	0.0	7	6,249	nw.	36	nw.	10	14	11	6	4.3	5.5	T.
Valentine	2,598	47	54	27.33	30.21	−.09	13.4	−5.5	50	31	26	−30	4	0	48	11	8	81	0.25	−0.3	7	6,001	w.	32	nw.	15	12	11	8	4.9	4.5	0.0
Sioux City	1,135	94	164	28.93	30.22	+.07	13.0	−4.8	48	29	22	−30	5	4	46	11	7	77	0.13	−0.4	4	8,504	nw.	37	nw.	10	14	10	7	4.6	1.6	T.
Huron	1,306	59	74	28.74	30.23	+.07	9.2	−2.1	50	30	21	−31	5	−2	43	7	3	79	0.09	−0.4	5	7,117	nw.	36	nw.	15	14	14	3	3.7	0.9	0.0
Pierre	1,572	70	75	28.46	30.23	+.10	11.8	−4.2	51	30	23	−29	5	1	47	9	5	77	0.15	−0.3	6	5,566	nw.	36	n.	15	12	6	13	5.2	2.6	0.0
Yankton	1,233	49	57	28.81	30.21	+.05	12.5	−4.9	49	29	23	−27	5	2	40	....	....	....	0.28	−0.3	6	5,986	w.	27	nw.	10	11	14	6	5.0	3.4	T.

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1924*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature: Departure from normal.	Temperature: Maximum.	Temperature: Date.	Temperature: Mean maximum.	Temperature: Minimum.	Temperature: Date.	Temperature: Mean minimum.	Temperature: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F		° F	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles.								0-10	In.	In.
Northern Slope.							**16.7**	**−2.7**										**73**	**0.50**	**−0.4**										**5.9**		
Billings	3,140	5	......	......	......	......	17.7	......	53	30	30	−31	1	5	50	......	......	......	0.31	......	5	......	nw.	......	......	......	19	2	10	......	6.8	0.0
Havre	2,505	11	44	27.40	30.19	+.09	11.0	−1.9	55	31	21	−32	1	1	53	9	7	83	0.48	−0.2	4	6,563	w.	34	sw.	5	9	7	15	6.0	4.8	0.0
Helena	4,110	87	112	25.84	30.22	+.07	18.0	−2.2	53	31	26	−27	1	10	32	16	12	78	0.48	−0.4	9	4,043	sw.	35	sw.	21	4	6	21	7.7	6.5	0.0
Kalispell	2,973	48	56	27.02	30.23	+.12	17.9	−2.5	46	31	25	−25	1	11	19	17	14	82	0.91	−0.7	11	2,638	nw.	24	w.	10	6	8	17	6.6	8.5	8.0
Miles City	2,371	48	55	27.56	30.26	+.14	10.6	−3.9	46	30	21	−31	1	0	41	8	3	72	0.35	−0.3	7	3,900	sw.	27	nw.	15	11	6	14	5.3	4.6	0.4
Rapid City	3,259	50	58	26.62	30.24	+.10	17.9	−4.1	50	31	31	−22	1	5	46	13	7	66	0.38	−0.1	5	5,050	w.	40	n.	15	6	14	11	6.0	4.2	T.
Cheyenne	6,088	84	101	23.94	30.13	+.08	24.7	−0.8	52	7	35	−7	3	14	35	20	12	59	0.38	0.0	6	12,405	w.	56	w.	10	6	15	10	6.0	4.3	T.
Lander	5,372	60	68	24.64	30.28	+.16	12.2	−6.1	47	31	24	−27	1	0	49	9	2	66	0.64	+0.2	4	2,339	sw.	44	w.	10	7	15	9	5.8	6.2	5.0
Sheridan	3,790	10	47	26.12	30.23	......	14.2	......	52	30	29	−27	1	0	49	11	7	75	0.98	......	9	2,650	s.	34	nw.	24	5	18	8	6.0	11.5	6.0
Yellowstone Park	6,200	11	48	23.88	30.28	+.14	16.2	−1.4	40	31	24	−17	4	8	30	14	10	75	0.80	−1.4	15	6,126	s.	29	s.	10	5	14	12	6.3	8.8	12.8
North Platte	2,821	11	51	27.15	30.23	+.11	21.4	−1.5	59	30	35	−20	5	8	43	16	11	75	0.08	−0.4	1	4,673	w.	32	n.	9	15	10	6	4.0	1.0	0.0
Middle Slope.							**28.0**	**−2.4**										**70**	**0.42**	**−0.3**										**3.9**		
Denver	5,292	106	113	24.70	30.14	+.09	29.6	−0.2	58	30	41	−5	1	18	44	23	16	61	0.52	+0.1	6	5,596	s.	36	ne.	3	14	11	6	4.5	8.6	0.0
Pueblo	4,685	80	86	25.29	30.13	+.08	27.8	−2.1	61	31	43	−10	20	12	46	22	15	64	0.41	+0.1	4	3,922	nw.	32	nw.	10	18	8	5	3.7	4.5	0.0
Concordia	1,392	50	58	28.66	30.21	+.07	20.8	−5.6	53	31	31	−18	5	10	41	18	14	78	0.95	+0.2	7	5,316	s.	29	nw.	10	17	7	7	3.8	9.2	T.
Dodge City	2,509	11	51	27.50	30.22	+.11	28.1	−0.9	63	31	42	−8	5	14	47	22	18	78	0.17	−0.3	4	7,077	nw.	37	nw.	9	21	4	6	2.9	2.1	0.0
Wichita	1,358	139	158	28.70	30.20	+.07	27.9	−3.4	62	30	38	−9	5	18	35	24	19	71	0.31	−0.5	4	10,028	s.	42	sw.	27	17	6	8	4.1	1.2	0.0
Broken Arrow	765	11	52	29.38	30.24	......	31.6	......	63	31	41	−2	5	23	31	......	......	......	1.36	......	8	10,164	s.	38	s.	9	15	4	12	4.8	1.3	0.0
Muskogee	652	4	......	......	......	......	34.4	......	66	30	44	0	5	24	36	......	......	......	1.47	......	9	......	e.	......	......	......	13	7	11	......	T.	0.0
Oklahoma City	1,214	10	47	28.89	30.23	+.12	34.0	−2.4	69	30	44	1	5	24	34	29	21	70	0.18	−1.2	4	8,720	s.	28	n.	19	19	2	10	3.6	0.1	0.0
Southern Slope.							**40.2**	**−1.8**										**61**	**0.18**	**−0.5**										**3.4**		
Abilene	1,738	10	52	28.35	30.21	+.12	40.2	−2.4	71	31	53	15	1	28	36	33	25	64	0.19	−0.7	2	7,538	s.	38	w.	9	16	7	8	4.0	T.	0.0
Amarillo	3,676	10	49	26.33	30.17	+.11	35.1	+1.2	65	30	49	7	1	21	41	27	21	67	0.13	−0.5	3	7,221	sw.	33	nw.	9	21	7	1	2.5	1.3	0.0
Del Rio	944	64	71	29.20	30.21	+.15	48.6	−3.7	77	24	56	26	7	37	43	......	......	......	0.14	−0.7	5	5,724	se.	34	n.	12	10	9	12	5.6	0.0	0.0
Roswell	3,566	75	85	26.43	30.14	+.10	36.8	−2.4	66	30	52	12	21	22	41	28	17	51	0.25	−0.2	2	5,294	s.	39	w.	9	27	4	0	1.4	1.6	0.0
Southern Plateau.							**42.1**	**−1.2**										**43**	**0.11**	**−0.6**										**1.3**		
El Paso	3,762	110	133	26.27	30.12	+.11	42.2	−1.9	66	31	54	21	6	30	32	33	20	45	0.40	−0.1	2	7,418	nw.	39	nw.	2	26	3	2	1.8	0.0	0.0
Santa Fe	7,013	38	53	23.22	30.16	+.12	27.0	−1.8	50	31	38	3	20	16	29	20	10	52	0.13	−0.5	3	5,512	n.	28	sw.	1	25	5	1	1.4	2.7	T.
Flagstaff	6,907	10	59	23.36	30.14	......	24.6	......	54	31	40	−12	2	10	45	......	......	......	0.34	......	2	......	nw.	30	ne.	14	27	2	2	......	2.5	T.
Phoenix	1,108	76	81	28.92	30.10	+.07	50.4	−0.8	74	31	66	28	3	35	39	40	27	48	0.00	−1.2	0	3,516	e.	28	e.	6	27	4	0	1.0	0.0	0.0
Yuma	141	9	54	29.97	30.12	+.07	53.0	−1.4	75	31	66	31	3	40	34	41	24	36	0.00	−0.4	0	3,202	n.	21	nw.	1	30	1	0	0.8	0.0	0.0
Independence	3,957	5	25	26.12	30.25	+.18	38.0	−0.2	65	31	54	7	2	22	40	27	10	35	0.00	−0.9	0	4,693	nw.	40	nw.	9	27	3	1	1.5	0.1	0.0
Middle Plateau.							**23.6**	**−4.6**										**74**	**0.25**	**−0.8**										**4.3**		
Reno	4,532	74	81	25.61	30.30	+.17	30.5	−2.0	62	30	44	−4	2	17	43	25	19	68	0.16	−1.6	4	2,724	ne.	41	sw.	8	15	8	8	4.1	2.4	0.0
Tonopah	6,090	12	20	24.13	30.29	......	28.6	......	54	31	36	−1	1	21	27	......	......	......	0.14	......	1	......	se.	......	......	......	......	......	......	......	2.0	0.0
Winnemucca	4,344	18	56	25.79	30.36	+.20	20.7	−7.9	48	31	35	−16	2	6	39	19	14	76	0.06	−1.0	3	5,218	ne.	20	nw.	1	10	5	16	6.0	1.3	T.
Modena	5,479	10	43	24.71	30.25	+.15	24.4	−2.3	53	31	40	−14	2	9	45	19	11	63	0.17	−0.6	3	6,040	w.	43	sw.	8	22	8	1	2.1	1.5	0.0
Salt Lake City	4,360	163	203	25.78	30.30	+.15	25.0	−4.2	42	29	32	8	2	18	21	23	20	80	0.49	−0.9	5	3,519	nw.	29	ne.	3	10	8	13	5.7	7.4	0.9
Grand Junction	4,602	60	68	25.53	30.28	+.22	17.2	−6.8	44	29	30	−4	13	4	31	14	12	82	0.35	−0.1	5	2,468	nw.	14	se.	25	16	12	3	3.5	3.5	0.0
Northern Plateau.							**25.5**	**−3.0**										**80**	**0.73**	**−0.9**										**7.3**		
Baker	3,471	48	53	26.61	30.33	+.17	21.4	−2.5	44	31	30	−12	1	12	26	20	17	82	0.34	−1.0	6	4,195	se.	20	nw.	10	5	5	21	7.3	5.2	0.0
Boise	2,739	78	86	27.39	30.38	+.19	23.6	−6.0	48	30	31	0	7	16	2	22	18	77	0.40	−1.5	7	2,45	nw.	17	w.	27	6	11	14	6.8	5.5	0.0
Lewiston	757	40	48	29.42	30.26	+.10	30.2	−2.3	50	29	36	−2	4	24	27	......	......	......	0.79	−0.8	13	3,165	e.	16	w.	10	4	6	21	7.9	3.3	0.0
Pocatello	4,477	60	68	25.59	30.31	+.11	22.1	−2.6	42	31	31	−6	4	13	28	19	16	77	0.45	−0.2	11	6,526	se.	42	sw.	10	5	15	11	6.2	5.8	0.0
Spokane	1,929	101	110	28.13	30.27	+.15	25.0	−2.5	53	31	31	−7	1	19	22	24	22	86	1.26	−1.0	13	3,647	sw.	22	sw.	9	1	8	22	8.1	5.0	0.0
Walla Walla	991	57	65	29.16	30.27	+.12	30.7	−2.0	67	31	37	2	3	24	30	28	25	80	1.16	−0.8	11	3,375	s.	21	sw.	9	6	7	18	7.3	3.8	0.0
North Pacific Coast Region.							**41.2**	**+0.9**										**84**	**4.46**	**−2.3**										**8.3**		
North Head	211	11	56	29.90	30.14	+.09	43.4	+1.3	56	25	47	17	1	40	13	41	38	82	5.11	−1.6	24	15,050	e.	75	s.	29	4	3	24	8.3	0.6	0.0
Port Angeles	29	8	53	......	30.14	......	39.6	......	54	26	45	13	1	35	18	......	......	......	2.54	−2.9	19	4,024	s.	26	sw.	17	0	6	25	......	0.3	0.0
Seattle	125	215	250	30.04	30.18	+.13	41.0	+1.5	59	31	45	17	1	37	16	39	36	81	4.10	−0.7	22	6,016	se.	43	sw.	9	2	3	26	8.7	0.3	0.0
Tacoma	213	113	120	29.96	30.17	+.13	40.4	+1.6	60	31	46	13	1	35	16	......	......	......	3.27	−2.5	17	4,107	s.	34	s.	9	2	4	25	8.7	9.5	0.0
Tatoosh Island	86	9	57	29.99	30.09	+.11	42.8	+1.6	54	27	46	25	1	40	11	41	39	89	10.83	−1.3	25	15,709	e.	68	s.	31	2	5	24	8.5	0.2	0.0
Yakima	1,071	5	......	29.03	30.26	......	26.0	......	59	31	35	−7	1	16	39	......	......	......	0.59	......	8	......	......	......	......	......	......	......	......	......	6.7	0.0
Medford	1,425	4	......	......	......	......	37.8	......	68	31	46	14	2	30	33	......	......	......	0.51	......	8	......	......	......	......	......	3	3	25	......	2.5	0.0
Portland, Oreg.	153	68	106	30.05	30.21	+.13	38.5	−1.0	60	31	44	14	1	34	17	37	32	84	3.94	−2.7	16	4,359	se.	26	e.	4	2	3	26	8.6	4.8	0.0
Roseburg	510	9	57	29.66	30.22	+.12	41.5	+.03	66	31	48	17	1	35	23	39	37	84	1.43	−4.3	16	1,59[illegible]	nw.	13	se.	29	3	10	18	7.1	0.6	0.0
Middle Pacific Coast Region.							**47.7**	**0.0**										**72**	**2.32**	**−2.2**										**4.2**		
Eureka	62	73	89	30.14	30.21	+.11	48.0	+1.1	68	30	55	29	2	41	23	44	41	78	1.95	−5.7	10	4,542	se.	40	nw.	8	12	6	13	5.2	T.	0.0
Point Reyes	490	7	18	29.61	30.13	......	50.7	+1.3	66	20	56	37	1	46	21	......	......	......	3.29	......	6	12,207	s.	64	nw.	13	15	9	7	4.1	0.0	0.0
Red Bluff	332	50	56	29.84	30.21	+.09	44.6	−1.2	68	15	55	20	2	34	38	40	32	64	3.41	−0.5	6	3,352	nw.	27	nw.	14	18	4	9	3.7	8.0	0.0
Sacramento	69	106	117	30.13	30.20	+.08	45.1	−0.7	63	14	54	26	2	36	26	42	37	75	1.80	−1.9	7	4,186	n.	28	nw.	14	18	3	10	3.9	0.0	0.0
San Francisco	155	208	243	30.01	30.18	+.07	50.2	+0.3	65	15	57	37	2	44	19	45	40	72	2.75	−1.6	6	4,804	n.	31	n.	14	16	7	8	4.1	0.0	0.0
San Jose	141	12	110	30.03	30.19	......	47.4	−0.9	67	15	61	23	2	34	37	......	......	......	1.70	−1.2	5	4,079	s.	30	ne.	14	17	6	8	3.9	0.0	0.0
South Pacific Coast Region.							**53.2**	**+1.6**										**60**	**0.66**	**−2.2**										**2.9**		
Fresno	327	89	98	29.84	30.20	+.10	46.7	+0.5	68	25	57	24	2	36	29	41	34	69	0.54	−1.1	3	3,073	nw.	24	nw.	13	15	7	9	3.8	0.0	0.0
Los Angeles	338	159	191	29.76	30.13	+.05	58.5	+3.9	80	6	69	37	2	48	30	46	33	47	0.36	−2.5	2	3,941	ne.	25	n.	1	24	6	1	1.9	0.0	0.0
San Diego	87	62	70	30.01	30.11	+.04	55.2	+0.9	77	5	65	39	2	46	31	48	41	64	0.26	−1.7	4	3,660	nw.	24	nw.	1	20	7	4	2.9	0.0	0.0
San Luis Obispo	201	32	40	29.94	30.16	+.07	52.5	+0.9	80	5	67	30	24	38	48	43	34	60	1.46	−3.3	4	2,271	n.	18	ne.	12	19	10	2	2.9	0.0	0.0
West Indies.																																
San Juan, P. R.	82	9	54	29.98	30.07	......	74.7	−0.3	81	21	79	66	30	70	13	......	......	......	3.07	−1.6	25	11,325	e.	42	e.	2	10	16	5	4.6	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.73	29.85	.00	80.1	+0.1	90	16	88	69	7	72	20	72	71	84	T.	−0.9	0	8,205	nw.	27	nw.	12	8	23	0	4.5	0.0	0.0
Colon	36	7	97	29.80	29.84	.00	80.7	+0.7	88	26	85	73	31	77	12	74	72	81	0.61	+3.0	12	11,718	n.	29	ne.	4	5	21	5	5.3	0.0	0.0
Alaska.																																
Juneau	80	11	54	......	......	......	30.4	......	47	30	34	6	24	27	16	29	25	82	6.85	......	27	5,398	s.	36	e.	24	3	0	28	9.5	32.0	T.

TABLE II.—*Data furnished by the Canadian Meteorological Service, January, 1924.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure. Station reduced to mean of 24 hours.	Pressure. Sea level reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature of the air. Mean max. + mean min. ÷ 2.	Temperature of the air. Departure from normal.	Temperature of the air. Mean maximum.	Temperature of the air. Mean minimum.	Temperature of the air. Highest.	Temperature of the air. Lowest.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Total snowfall.
	Feet.	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*In.*	*In.*	*In.*
St. Johns, N. F.	125	29.61	29.75	− 11	22.7	−1.1	28.9	16.6	48	5	5.96	+0.05	38.0
Sydney, C. B. I.	48	29.94	29.99	+.06	23.2	+2.7	31.8	14.5	46	−7	6.44	+1.34	39.0
Halifax, N. S.	88	29.91	30.02	+.05	24.5	+2.7	34.5	14.6	49	−10	6.47	+0.70	22.5
Yarmouth, N. S.	65	29.93	30.00	.00	28.6	+2.3	37.4	19.9	50	−6	6.08	+0.67	23.3
Charlottetown, P. E. I.	38	29.92	29.96	.00	19.2	+2.2	29.2	9.2	45	−15	2.47	−1.49	16.5
Chatham, N. B.	28	29.88	29.92	−.05	10.0	+0.2	23.1	−3.1	42	−28	3.35	−0.24	25.7
Father Point, Que.	20	29.95	29.98	.00	5.2	−2.8	14.9	−4.4	36	−22	2.50	−0.35	20.6
Quebec, Que.	296	29.70	30.04	+.02	10.0	+0.9	19.2	0.8	37	−26	4.73	+0.72	41.3
Montreal, Que.	187	29.83	30.06	+.02	14.3	+2.6	24.1	4.4	41	−23	4.96	+1.23	35.5
Ottawa, Ont.	236	29.79	30.08	+.05	12.6	+3.0	24.3	1.0	44	−28	5.59	+2.60	45.4
Kingston, Ont.	285	29.75	30.09	+.04	21.3	+4.2	30.3	12.3	45	−23	3.41	−0.04	8.9
Toronto, Ont.	379	29.66	30.09	+.04	23.4	+2.0	30.8	16.0	43	−6	4.89	+1.97	25.4
Cochrane, Ont.	930				−7.0		3.6	−17.6	34	−42	1.30		13.0
White River, Ont.	1,244	28.59	30.00	−.01	−7.3	+6.9	8.8	−23.4	34	−57	1.61	−0.08	16.1
Port Stanley, Ont.	592	29.48	30.15	+.08							3.82	+0.83	12.6
Southampton, Ont.	656	29.30			20.6	+0.2	27.5	13.7	40	−11	4.62	+0.57	35.6
Parry Sound, Ont.	688	29.32	30.06	+.05	12.8	−1.0	23.4	2.2	38	−30	7.01	+2.93	66.9
Port Arthur, Ont.	644	29.33	30.09	+.02	−2.2	−5.3	6.8	−11.1	40	−30	0.41	−0.41	4.1
Minnedosa, Man.	1,690	28.16	30.11	+.01	−5.0	+2.2	4.6	−14.6	34	−35	0.95	+0.15	9.5
LePas, Man.	860				−9.1		1.2	−19.4	38	−37	0.26		2.6
Qu'Appelle, Sask.	2,115												
Medicine Hat, Alb.	2,144	27.70	30.07	.00	10.9	+5.4	20.8	1.0	51	−30	1.92	+1.35	19.2
Moose Jaw, Sask.	1,759				1.9		11.0	−7.2	47	−36	0.36		3.6
Swift Current, Sask.	2,392												
Calgary, Alb.	3,428	26.37	30.12	+.09	13.7	+5.3	27.1	0.3	57	−25	0.84	+0.31	8.4
Banff, Alb.	4,521	25.32	30.13	+.13	12.5	+0.4	21.7	3.2	45	−35	0.69	−0.50	6.9
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450												
Battleford, Sask.	1,592												
Kamloops, B. C.	1,262	28.88	30.23	+.07	21.5	−1.5	27.2	15.8	50	−17	1.64	+0.82	16.4
Victoria, B. C.	230	29.88	30.14	+.07	40.3	+1.8	43.9	36.7	55	17	2.65	−2.74	0.1
Barkerville, B. C.	4,180	25.57	29.98	+.09	20.3	+2.5	26.9	13.7	41	−25	2.34	−0.26	22.2
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170				38.2		42.8	33.6	53	15	18.82		0.3

LATE REPORTS, DECEMBER, 1923.

Father Point, Que.	20	29.92	29.95	.00	23.7	+8.3	28.8	18.6	50	−2	2.53	−0.30	15.7
Winnipeg, Man.	760	29.10	29.96	−.06	17.8	+13.7	25.5	10.0	44	−20	0.29	−0.62	2.9
Medicine Hat, Alb.	2,144	27.57	29.89	−.08	24.9	+6.7	34.1	15.7	54	−30	0.41	−0.14	4.1
Calgary, Alb.	3,428	26.26	29.96	+.02	21.3	+3.1	35.3	7.4	52	−35	1.08	+0.49	10.8
Banff, Alb.	4,521	25.24	30.00	+.06	18.3	−0.8	25.7	10.9	41	−40	1.97	+0.76	19.7
Kamloops, B. C.	1,262	28.71	30.03	+.09	29.7	+0.8	34.6	24.8	48	−17	1.23	+0.45	8.0
Barkerville, B. C.	4,180	25.45	29.84	−.04	19.4	−1.5	26.1	12.7	40	−28	4.84	+1.67	45.8

SEISMOLOGICAL REPORTS FOR JANUARY, 1924.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, March 3, 1924.]

SEISMOLOGICAL ABBREVIATIONS USED IN THE INSTRUMENTAL REPORTS.

CHARACTER OF THE EARTHQUAKE.

I=noticeable.
II=conspicuous.
III=strong.
d=(terræ motus domesticus)=local earthquake (sensible or felt).
v=(terræ motus vicinus)=near-by earthquake (within 1,000 km).
r=(terræ motus remotus)=distant earthquake (1,000 to 5,000 km. distant).
u=(terræ motus ultimus)=very distant earthquake (beyond 5,000 km.).
Δ=distance to epicenter.

PHASES.

P=(undæ primæ)=first preliminary tremors.
PR_n=P waves reflected n times at the earth's surface.
S=(undæ secundæ)=second preliminary tremors.
SR_n=S waves reflected n times at the earth's surface.
PS=transformed waves; longitudinal (P) to transverse (S) or vice versa.
L=(undæ longæ)=long waves in the principal portion.
M=(undæ maximæ)=greatest motion in the principal portion.
C=(coda)=trailers.
O=time at epicenter.
L_{rep_1}=long waves reaching the station from the antiepicenter (40,000 km. −Δ).
L_{rep_2}=long waves again reaching the station from the antiepicenter (40,000 km. +Δ).
F=(finis)=end of perceptible trace.

NATURE OF THE MOTION.

i=(impetus)=abrupt beginning.
e=(emersio)=gradual appearance.
T=(period)=twice time of oscillation.
A=amplitude of earth's movement, reckoned from the zero line. E, N, or Z attached to a symbol signifies the E–W, the N–S, or the vertical component, respectively, thus:
P_E is the E–W component of P.
P_N is the N–S component of P.
P_Z is the vertical component of P.
μ=micron, $\frac{1}{1000}$ mm.

INSTRUMENTAL CONSTANTS.

T_0=period of instrument.
V=magnification of instrument.
ϵ=damping ratio.

List of instrumental stations from which reports are received.

Location.	Latitude, N.			Longitude, W.			Elevation, meters.	Description of instruments.	Instrumental constants. E-W.			N-S.			Institution.	Director.
	°	'	"	°	'	"			V	T_0	ϵ	V	T_0	ϵ		
ALASKA.																
Sitka	57	03		135	20	06	15.2	Bosch-Omori 10-kg., horizontal pendulum, two comp.	10	13.9	......	10	18.1	......	U. S. Coast and Geodetic Survey, Magnetic Observatory.	F. P. Ulrich.
ARIZONA.																
Tucson	32	14	48	110	50	06	769.6	....do	10	17.0	......	10	19.6	......	....do	A. K. Ludy.
CALIFORNIA.																
Point Loma	32	43	03	117	15	10	91.4	Two-component C. D. West seismoscope.	......	......	......	......	......	......	Theosophical University, Meteorological Station.	F. J. Dick.
COLORADO.																
Denver	39	40	36	104	56	54	1,655	Wiechert 80-kg., astatic horizontal pendulum.	......	......	......	......	......	......	Regis College, Earthquake Station.	A. W. Forstall, S. J.
DISTRICT OF COLUMBIA.																
Washington	38	54	25	77	04	24	42.4	Wiechert 200-kg., inverted pendulum; *80-kg. vertical.*	165	5.4	0	142	5.2	0	Georgetown University, Seismological Station.	F. A. Tondorf, S. J.
									VERTICAL:	*V, 80; To, 3.0.*						
								Bosch photographic pendulums (horizontal), 200 g.	133	5.0	......	133	5.0	......		
								Mainka bifilar pendulums, 135-kg., horizontal.	47	9.0	......	59	9.0	......		
								Bosch-Omori 25-kg., horizontal.	13.7	8.8	......	13.5	8.6	......		
Washington	38	54	12	77	03	03	21	Marvin, inverted pendulum, undamped, mechanical registration.	110	6.4	([3])	110	6.4	......	U. S. Weather Bureau	W. J. Humphreys.
HAWAII.																
Honolulu	21	19	12	158	03	48	15.2	Milne-Shaw	150	12	[5] 30:1	150	12	[5] 30:1	U. S. Coast and Geodetic Survey, Magnetic Observatory.	W. M. Hill.
ILLINOIS.																
Chicago	41	47		87	37		180.1	Two Milne-Shaw horizontal pendulums, 0.45-kg.	150	12	[3] 20:1	150	12	[3] 20:1	U. S. Weather Bureau, University of Chicago.	H. J. Cox.
MARYLAND.																
Cheltenham	38	44		76	50	30	*ca.* 71.6	Two Bosch-Omori 10-kg.	10	15	......	10	15	......	U. S. Coast and Geodetic Survey, Magnetic Observatory.	George Hartnell.
MASSACHUSETTS.																
Cambridge	42	22	36	71	06	59	5.4	Two Bosch-Omori 100-kg., horizontal pendulum, mechanical registration.	80	23	1:5	50	25	[4] 1:5	Harvard University, Seismographic Station.	J. B. Woodworth.
MISSOURI.																
St. Louis	38	38	17	90	13	58.3	160.4	Wiechert 80-kg., inverted pendulum.	80	7	5:1	......	......	......	St. Louis University, Geophysical Observatory, Earthquake Station.	Geo. E. Rueppel.
NEW YORK.																
Ithaca	42	26	58	76	29	09	242.6	Bosch-Omori 25-kg., horizontal pendulum, mechanical registration.	12	21	4:1	13	24	4:1	Cornell University, Department of Geology, Seismograph Station.	P. S. Sheldon.
New York	40	51	47	73	53	08	23.9	Wiechert 80-kg., horizontal pendulum.	59.5	4.8	2.8	78	5	2.9	Fordham University, Seismologic Station.	F. W. Sohon, S. J.
CANAL ZONE.																
Balboa Heights	8	57	39	79	33	29	*ca.* 36	Two Bosch-Omori 100-kg. and 25-kg.	35 10	20	......	35 10	20 20	......	Panama Canal, Department Operation and Maintenance, section of meteorology and hydrography, Seismologic Station.	R. Z. Kirkpatrick, chief hydrographer.
PORTO RICO.																
Vieques	18	08	50	65	26	50	19.1	Bosch-Omori 10-kg	10	17.2	......	10	19.1	......	U. S. Coast and Geodetic Survey, Magnetic Observatory.	R. R. Bodle.
VERMONT.																
Northfield	44	10		72	41		256	Bosch-Omori mechanical registration, 25-kg.	10	15	......	10	16	......	Local Office, U. S. Weather Bureau.	Wm A. Shaw.
CANADA.																
Ottawa [6]	45	23	38	75	42	57	83	......	......	......	......	......	......	......	Dominion Observatory, Earthquake Station.	E. A. Hodgson.
Toronto	43	40	01	79	23	54	113.7	Milne horizontal pendulum, North, in the meridian.	......	18	[2] 0''.46	......	......	......	Dominion Meteorological Service.	
Victoria	48	24		123	19		67	Milne-Shaw horizontal pendulum, North and E-W.	......	......	......	......	......	......	....do	

[1] Pillar inclination, 1 mm.
[2] 1'' arc tilt, 26.6 mm.
[3] 1 mm.=4''.
[4] 15 mm.=60 sec.
[5] Sensitivity: E. 0.171; N. 0.200.
[6] For instruments and constants, see Table 1.

For the reports of the stations at the University of California, Berkeley, Calif., and at the Lick Observatory, Mount Hamilton, Calif., see *Bulletin of the Seismographic Station, University of California;* for the report of the station at the University of Santa Clara, Santa Clara, Calif., see *Record of the Seismographic Station, University of Santa Clara.*

TABLE 1.—*Noninstrumental earthquake reports, January, 1924.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ALABAMA.	° ′	° ′						
1924.	*H. m.*						*Sec.*			
Jan. 1	3 20	Sheffield	34 50	87 40	4			Rattling	Felt by many	H. F. Little, P. M.
	3 30	Florence	34 50	87 40	2	1	Brief.	None	Felt by several	O. Coburn.
		ARKANSAS.								
	3 00	Marked Tree	35 30	90 25	5	1	30*ca*	Rumbling	Felt by many	C. Walton.
		Newport	35 35	91 10	2	1	10	Yes	Felt by several	G. L. Robinson.
	3 05	Black Rock	36 05	91 00	4	1	12	Rumbling	do	V. C. Howe.
		Blytheville	35 53	89 55	5	1	10-20	do	Felt by everyone	E. E. Ridings.
		Corning	36 35	90 30		1	4-5	do	Felt by many	N. E. Skinner.
		Earle	35 15	90 30	5	2	10, 35	do	Felt by nearly everyone	E. S. Barrentine.
		Helena	34 30	90 30	5	1	25	do	Felt by many	J. A. Burnett.
		Jonesboro	35 55	90 35	5	1	30	None	do	T. S. Castleberry.
		do	35 55	90 35	5	2	25	Rumbling	Some damage	Sr. M. Modesta, O. S. B.
		Osceola	35 45	90 00				do	Felt by many	A. B. Smith.
		Pocohontas	36 15	91 00		1	60	do	Felt by several	Benedictine Sisters.
		Wilson	35 37	90 00	5	3	7	do	Felt by many	E. K. Sewell.
		Wynne	35 15	90 45	5	1	30*ca*	Faint	do	E. O. Allen.
	3 09	Hoxie	36 05	90 55	4	1		None	Felt by several	C. C. Cherry.
		CALIFORNIA.								
4	21 40	Salinas	36 41	121 39	2	1	1*ca*	None	Felt by several	E. D. Eddy.
5	22 52	Calexico	32 41	115 30	4	1	2	do	Felt by one	H. W. Rouse.
9	(?)	Eureka	40 48	124 10	4	1	4	do	Felt by many	J. M. Jones.
		ILLINOIS.								
1	3 06	Cairo	37 00	89 05	2	1	7*ca*	None	Felt by several	W. E. Barron.
	3 10	Anna	37 30	89 15	2	2	5-6		Felt by few	Mrs. E. V. Hale.
		KENTUCKY.								
1	3 00?	Calhoun	37 30	87 15		1	Brief.		Felt by few	Dr. W. S. Haynes, *et al.*
	3 05	Clinton	36 45	89 00	Slight.	1	45	Rumbling	Felt by several	D. Johnson.
		Hickman	36 34	89 12		1	10	do	Felt by many	
	3 15	Columbus	36 45	89 05		2	20*ca*	do	Felt by several	P. M. Ray.
		Cadiz	36 55	87 50	4	3		do	do	Miss L. Burbon.
	3 20	La Center	37 05	89 00	2	1	Brief.			B. Clements.
		MISSISSIPPI.								
1	3 06	Corinth	35 00	88 25	4			None	Felt by several	H. E. Meeks.
		OREGON.								
5	23 15?	Stanfield	45 50	119 15	4-5	1	3-5	None	Felt by several	R. N. Hanley.
6	23 09	Milton	45 55	118 20	5	1	10-15	Faint	Felt by many	C. D. Hobbs, C. O.
	23 10	Weston	45 55	118 30	5?	1	Few.	None	do	M. A. Barken.
		SOUTH CAROLINA.								
1	1 06	Greenville	34 50	82 30	5	1	Several.	Rumbling	Felt by many	C. E. Morgan.
		TENNESSEE.								
	3 00	Brownsville	35 40	89 15	5	2	2	None	Felt by many	R. Y. Moses.
		Union City	36 30	89 00	5					S. D. Woosley.
	3 05	Brownsville	35 40	89 15	4	1	Few.	None	Felt by many	F. J. Nunn, P. M.
		Moscow	35 05	89 20	2	1	Few.	Rumbling	Felt by several	W. R. Burdison.
		Savannah	35 15	88 15	5	1		Rattling	Felt by many	F. W. Kendon.
		Union City	36 30	89 00	5	2	5	Rumbling	do	J. C. Burdeisly.
	3 05 35	Memphis	35 10	90 00	5	3	2	do	Felt by several	J. P. Young.
	3 10	Covington	35 30	89 45		2	15			R. H. Gunn.
	3 10?	Memphis	35 10	90 00	4	2	15*ca*	Rumbling	Felt by many	A. R. Long.
	3 12	do	35 10	90 00	4	2	1-2	None	do	G. E. Wilcox.
		UTAH.								
1	23 15	Orderville	37 20	112 40	2	1	Brief.	Faint	Felt by several	F. A. Porter.
		WASHINGTON.								
6	13 09	Walla Walla	46 00	118 30	4	1	6	None	Felt by many	C. C. Garrett.
		WYOMING.								
11	23 30	Yellowstone	45 00	110 40	Faint.	1		None	Felt by several	B. C. Lacombe.

TABLE 2.—*Instrumental seismological reports, January, 1924.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

ALASKA. *U. S. C. and G. S. Magnetic Observatory, Sitka.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1924.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 14		P_E?	21 00 22	6				Strong wind tremors.
		S_E?	21 08 36	10				
		F_E	21 27 ..					
30		eL_E	21 25 06					Weak phases obscured by wind tremors.
		eL_N	21 24 53	20				
		M_E	21 26 32	17	*100			
		M_N	21 25 50	17		*600		
		C_N	21 27 20	12				
		F_E	21 38 ..					

ARIZONA. *U. S. C. and G. S. Magnetic Observatory, Tucson.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1924.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 14		P_E	21 03 00					Nothing on NS.
		S_E	21 13 16					
		L_E	21 32 32	24				
		M_E	21 34 01	24	*300			
		F_E	21 52 ..					
25		e_E	6 09 23					Do.
		e_E	6 13 45					
		M_E	6 15 59	8	*200			
		F_E	6 33 ..					

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1924.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 2			15 00 00		50	50		Tremors during preceding 24 hours.
6					50	50		

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1924.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 4		e?	22 00 20					
		F	22 10 *ca.*					
14		e	21 06 30					
		S?	21 14 30					
		eL	21 38 ..	30				
		L	21 44 ..	32				
		L	21 53 ..	16				
		F	22 15 *ca.*					
21		P?	2 05 23					
		S?	2 13 05					
		F	2 35 ..					
29		P	2 05 46				7,400	
		S	2 14 37					
		eL	2 36 ..					
		F	2 50 *ca.*					
30		P	20 59 06					
		S?	21 02 36					
		eL	21 05 ..					
		F	21 25 *ca.*					
31		e	1 10 36					
		S?	1 14 15					
		F	1 20 *ca.*					

HAWAII. *U. S. C. and G. S. Magnetic Observatory, Honolulu.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1924.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 7		e_E	10 09 27					
		e_N	10 10 33					
		M_E	10 13 45	7	30			
		M_N	10 13 45	10		45		
		F_E	10 23 ..					
		F_N	10 19 ..					
12		e_E	14 11 ..					
		e_N	14 14 ..					
		F_E	14 22 ..					
		F_N	14 25 ..					
14		P_N	21 00 ..					Exact time of P_N doubtful on account of hour break.
		e_E	21 07 25					
		S_E	21 07 58	17				
		S_N	21 07 40	12				
		S_E2	21 13 36	22				
		$L1_E$	21 17 08	11				

*Trace amplitude.

HAWAII. *U. S. C. and G. S. Magnetic Observatory, Honolulu*—Con.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1924.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 14		$iL2_E$	21 29 22	20				
		L_N	21 16 15	13				
		M_E	21 37 17	19	60			
		M_N	21 17 14	13		35		
		C_E	21 41 ..					
		F_E	22 05 ..					
		F_N	21 59 ..					
16		e	21 52 36					
		F	22 00 ..					
21		P_N(?)	2 02 52					
		S	2 07 28					
		$L1_E$	2 11 18					
		$L2_E$	2 12 34					
		L_N	2 11 30					
		M_E	2 12 40	13	20			
		M_N	2 12 46	13		20		
		C	2 19 ..					
		F_E	2 36 ..					
		F_N	2 34 ..					
25		S_E(?)	6 14 22					
		S_N(?)	6 14 15					
		e_E	6 20 55					
		e_N	6 20 15					
		L_E	6 25 12	7				
		L_N	6 22 18	10				
		M_E	6 28 20	5	45			
		M_N	6 27 19	8		45		
		C_N	6 36 ..	6				
		F_E	7 29 ..					
		F_N	7 23 ..					
26		e_E	3 37 37					
		e_N	3 38 ..					
		F_E	3 52 ..					
		F_N	3 50 ..					
29		S_E(?)	2 21 45	20				
		L_E	2 39 42	22				
		L_N	2 40 00	20				
		M_E	2 41 06	20	40			
		M_N	2 40 43	20		30		
		F	3 21 ..					

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1924.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 4		P	21 59 51				1,600	
		S	22 02 35					
		L	22 03 18	16				
		F	22 25 *ca.*					
7		P	10 11 22					
		L	10 24 02	18				
		F	11 10 *ca.*					
12		eL	14 32 ..	22				
		F	14 50 ..					
14		P	21 03 25				9,100	
		S	21 13 41					
		L	21 32 20	30				
		L	21 40 30	22				
		L	21 50 ..	18				
		L	22 02 30	16				
		F	23 40 *ca.*					
21		P	2 04 40				5,800	
		S	2 12 05					
		L?	2 20 40					
		L	2 36 ..	16				
		F	3 *ca.* ..					Heavy micros.
25		P?	6 01 58					Apparently two quakes superimposed, with heavy micros.
		S?	6 12 04					
		F	8 *ca.* ..					
29		P	2 06 17				7,600	
		S	2 15 16					
		L	2 26 30	22				
		L	2 41 ..	18				
		F	5 *ca.* ..					
30		P	20 59 58				2,500	
		S	21 04 03					
		L	21 06 12					
		F	22 20 *ca.*					
31		P	1 10 10				2,800	
		S	1 14 36					
		F	2 *ca.* ..					

TABLE 2.—*Instrumental seismological reports, January, 1924*—Continued.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

			H. m. s.	Sec.	μ	μ	Km.	
1924. Jan. 30		e_E	21 04 24	3				No definite M on NS.
		e_N	21 04 47	2				
		e_N	21 05 14	3		*300		
		e_E	21 07 16	9				
		M_E	21 07 54	9	*300			
		C_E	21 08 16					
		C_N	21 08 ..					
		F_E	21 11 ..					
		F_N	21 14 ..					

NEW YORK. *Fordham University, New York.*

			H. m. s.	Sec.	μ	μ	Km.	
1924. Jan. 6		i	9 32 30					
		L	9 32 50	5	*200			
		F	9 34 ..					
11		eL	17 12 ..	20				F lost in micros.
14		e	21 37 17					
		L	21 39 19	20	*100			
		F	21 48 16					

CANAL ZONE. *Panama Canal, Balboa Heights.*

			H. m. s.	Sec.	μ	μ	Miles.	
1924. Jan. 1		P	8 47 40				140 *ca.*	Also very slight tremors between 9:12:24 and 9:15:00.
		L_E	8 48 28					
		L_N	8 48 20					
		M_E	8 48 31		*1,400			
		M_N	8 48 22			*4,000		
		F_E	8 51 25					
		F_N	8 51 36					
2								Slight tremors, 20;29:59 to 20:33.
24								Very slight tremors 19:44:42 to 19:47:42; and on NS at 22:48:18.
25								Very slight tremors on NS, 6:08:00 to 6:18:00.
26								Slight tremors, 2:10 to 2:21.
29								Slight tremors, 2:03:20 to 3:00; and 12:09:50 to 12:11.
30								Slight tremors on NS, 19:03:00 to 19:19.
31								Slight tremors on NS, 1:07 to 1:17.

VERMONT. *U. S. Weather Bureau, Northfield.*

			H. m. s.	Sec.	μ	μ	Km.
1924. Jan. 30		eL	21 09 ..				
		F	21 20 *ca*				

CANADA. *Dominion Observatory, Ottawa.*

Instruments—Fixed constants.

Instrument.	Symbol.	Registration.	Damping.	Paper speed.	Mass.
Bosch	I	Photographic	Air	15 mm. per min	200 g.
Do	II	do	Magnetic	do	200 g.
Milne-Shaw	17	do	do	8 mm. per min	1 lb.
Do	23	do	do	do	1 lb.
Deformation	D	do	Air	17 mm. per min	20 g. ca.
Spindler Hoyer	W	Smoked sheet	do	15 mm. per min	80 Kgm.

Instruments—Determined constants.

Instrument.	T_o	r	v	ε	Comp.	Determined.
I	5.5		120	2:1	NS	Apr. 4, 1923
II	5.4		120	15:1	EW	Aug. 21, 1923
17	12.0		250	20:1	EW	Jan. 9, 1924
23	12.0		250	20:1	NS	Jan. 9, 1924
D	37.6			13:10	EW	Jan. 7, 1924
D	36.9			13:10	NS	Jan. 7, 1924
W	5.5		160	4:1	Vert	Aug. 22, 1923

*, Trace amplitude.

CANADA. *Dominion Observatory, Ottawa*—Continued.

			H. m. s.	Sec.	μ	μ	Km.	
1924. Jan. 4		i	22 01 35					
		e	22 02 22	12	1			
		eL	22 04 ..	22	3			
		M	22 05 12	12	7			
		L	22 09 ..					Irregular.
		F	22 20 *ca*					
7		e	10 20 54					Do.
		eL	10 25 ..					Irregular.
		F	10 35 *ca*					
11		e	0 07 14					Sinusoidal L waves.
		i	0 07 49					
		eL	0 27 30					Micros.
		L	0 32 *to*	22	1			
		L	0 37 ..					
		F	0 50 ..					
11		(eL)	21 00 ..					Small sinusoidal L waves.
		L	21 02 ..	18	1	1		
		F	21 30 *ca*					
12		e?	(13 35)					About time sheets were changed. Time marks uncertain.
		eL	(14 35)					
		L	(14 50)					
		F	(15 00)					
14		O	20 51 07				9,300	Tokio and Yokohama.
		eP	21 03 35					
		PR1	21 07 35					
		iS	21 14 00					
		i	21 14 36					
		eL17	21 31 30					
		M 17	21 45 ..	23	52			
		M23	21 47 ..	23		49		
		L	21 58 ..	14	8	8		
		L	22 20 ..	14	5	4		
		L	22 45 ..	14	3	2.5		
		L	23 00 ..	14	1.5	1		
		F	23 50 *ca*					
15		eL	3 31 ..					Preliminaries lost in micros.
		M	3 58 ..	20	3			
		L	4 10 ..	15	1			
		F	4 20 ..					
16		e	(22 02 24)					Irregular waves with sharp disturbances; may not be seismic.
		e_E	(22 03 30)					
		e	(22 06 24)					
		eL?	(22 14) ..					
		F	(23 05) ..					
20		i	22 51 58	5	2.5	1		
		eL	22 58 30	?				
		L_E	23 02 ..	16	1			Very small.
		F	23 10 ..					
21		O	1 55 22				5,980	*Milne-Shaw seismographs not in operation after Jan. 21.*
		eP	2 04 52					
		PR1	2 07 26					
		eS	2 12 27					
		i	2 14 32					
		eL	2 23 ..					
		Me	2 26 ..	24	20			
		M_N	(2 35)..	18		8		
		L_E	2 37 ..	15	5.5			
		L_N	2 40 ..	12		3		
		L_E	2 54 ..	14	2			
		F	3 20 *ca*					
25		e	6 14 00					
		e	6 22 48					
		(eL)	6 27 48					
		M_N	6 29 48	6		(1)		
		L	6 33 30	6				
		F	6 40 ..					
29		O	1 55 02				8,120	
		iP_N	2 06 29					
		iS	2 15 55					
		eSR2?	2 35 00					
		eL_N	2 30 30					
		M_N	2 42 ..	19		25		
		M_E	2 39 ..	19	12			
		F	3 *ca*					
30		O	(20 53 29)				(3,270)	
		eP_N	(20 59 50)					
		$(ePR1_N)$	21 00 21					
		eS	(21 04 52)					
		eL	21 08 30					
		M_N	21 11 30	11		15		
		M_N	21 11 ..	12	25			
		F	21 30 *ca*					
31		e_N	1 09 36					Poorly defined except for i.
		e	1 13 24					
		i	1 17 50					
		eLe?	1 20 12					
		F	1 30 ..					

TABLE 2.—*Instrumental seismological reports, January, 1924*—Continued.

CANADA. *Meteorological Service of Canada, Toronto.*

1924.		*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 2	e	9 56 45					Micros. E/W component, oscillations caused by strong W. wind.
N	F	10 26 ..					
4	i	22 00 22					
	L	22 02 27	11				Uniform waves.
		22 03 30					
W	L	22 04 08					Micros going on.
	M1	22 05 24			24		
	M2	22 05 35	11				
	i	22 08 38	8				
	F	22 22 ..					
	i	22 00 28					
N	L	22 04 41	14				
	M1	22 05 30					
	M2	22 05 41	11	7			
	M3	22 05 51					
	F	22 20 ..					
6	L	18 16 30 18 18 00	6				Sinusoidal waves.
N	F						Micros. E/W component, wind interfered with phases.
7	i	10 12 10					
	e	10 16 30					
W	e	10 20 52					Micros going on.
	L	10 26 10	15		12		
	L	10 31 00	12				
	F						Micros.
N	i	10 12 13					
	i	10 20 52					Small micros previous to 10 12 13.
	L?	10 24 45					
	L	10 27 04					Irregular.
	F						Micros.
11	e	0 07 14					
W	L?	0 24 00					Small amplitude.
	L	0 27 00					Micros going on.
	F						Micros. N/S component does not appear disturbed.
12	L	14 33 23	15				Micros and strong W. wind effect boom.
W	L	14 41 52					
	F						Small micros.
	i	13 30 06					
	e	13 31 55					Micros interfere with phases.
N	e	13 42 17					
	e	13 33 30					
	F						Small micros.
14	O	20 51 17					
	eP	21 03 41	8-9				
N	iP	21 03 44					
	PR	21 07 19 30					
	eS	21 14 03	7				Quake felt at Tokyo and Yokohama.
	iS	21 14 06					
	i	21 14 41					
	e	21 21 03				9,230	
	eL	21 38 15	25				
	L	21 46 33 to 21 53 30	19				
	M1	21 52 23	18	15			
	M2	21 52 41					
	L	21 54 21					
	F	23 24 00					
	O	20 51 22					
W	eP	21 03 42					
	iP	21 03 44					
	PR	21 07 21	8				Do.
	eS	21 14 00					
	iS	21 14 03				9,150	
	i	21 14 30					
	i	21 14 48					
	e	21 28 02					
	eL	21 34 35					
	L	21 38 23	23				
	M1	21 48 51			23		
	M2	21 49 09	18				
	F	?0 48 ..					
15	L	3 57 43					Preliminary phases lost in micros.
W	L	3 58 02	15				
	F						Micros.
	iz	3 31 26					Very small amplitude, micros mask phases.
N	i	3 58 10					
	F						Micros.
16	L	22 14 15	23				Small active phases obscured by micros.
W	L	22 41 30	15				

CANADA. *Meteorological Service of Canada, Toronto*—Continued.

1924.		*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 16	F						Micros.
N	i	22 11 47					
	eL	22 18 43					Micros going on.
	F						Micros.
20	i?	22 50 45					Micros going on.
N	F						Micros. E-W component, winds effect boom.
21	iP	2 04 50					Preceded by micros.
	eS	2 12 21					
W	iS	2 12 29					
	eL	2 22 15	15				
	L	2 25 45	15				
	L	2 26 02	23		27		
	L?	3 48 21					
	F						Micros.
N	eP	2 04 49					Uniform P waves to 2h 05m 42s, 8 secs. period.
	iP	2 04 51	5				
	iPR1	2 07 23					
	eS	2 12 29					P & S well defined.
	iS	2 12 31					
	i	2 13 15					L waves very small and irregular.
	i	2 14 33					
	eL	2 22 14					
	L	2 36 38	15				Small amplitude.
		2 41 23					
	e	3 48 23					
	F						Micros.
25	eP	6 13 18					
	iP	6 13 23	8				
W	i	6 15 38					
	S S	6 19 00 6 19 23	11		4		Uniform waves.
		6 20 50	11				
	L	6 28 15 23	15		5		
	L	6 31 38	11		6		
	L	6 46 55	15				
	L	7 48 11	17				
	F						Micros.
25	eP	6 13 15					
	iP	6 13 25	8				
N	S	6 19 22 .. .. 30 to 6 20 45	11	4			Difficult seismogram to analyze. Uniform waves.
	i	6 27 25	8				
	eL	6 30 00	19				
	F	7 54 ..					
26	i?	2 14 45	4				
	e?	2 25 27	8				Micros going on.
N	L	2 32 15					Small amplitude, readings doubtful. E-W component, wind masked phases.
	F	Micros ..					
29	O	1 54 59					
	eP	2 06 17					
	eS i	2 15 34 2 15 38	12				
W	e	2 24 00					E well defined.
	e	2 25 00	15			7,950	
	L?	2 30 22					
	L	2 31 10	37				Northern Chili. Sinusoidal.
	M1	2 39 00	23		17		
	M2	2 39 23					
	M3	2 39 45					
	F						Micros
	O	1 55 02					
N	iP i	2 06 20 22	4				P & S well defined.
	iS	2 15 36	8	9			
	e	2 20 41					
	eSR	2 24 08					
	L	2 32 37					
	L	2 36 30	19				Sinusoidal.
		2 42 53	23			7,930	
	M1	2 39 51	23	19			Northern Chili.
	L	2 44 04					
	L	2 48 08	19				
	L	3 00 05	19				
	F						Micros
30	e	5 35 08					Small amplitude slow irregular, waves.
W	L	6 00 53					
	F	6 04 00					
N	e	5 34 45					
	F	5 52 00					
30	e	14 46 05					
	i	14 48 56	8				Small amplitude.
W							Sinusoidal small waves.
		14 51 38	8				

TABLE 2.—*Instrumental seismological reports, January, 1924*—Continued.

CANADA. *Meteorological Service of Canada, Toronto*—Continued.

1924.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 30		F?	15 16 ..					
N		e	14 46 06					Small sinusoidal.
			14 47 17					
			to					
			14 48 53	8				
		F	14 56 ..					
30		O	20 53 01					
		eP	20 59 20					P poorly defined.
W		eS	21 04 20					Irregular.
		eS	21 04 23					
		e	21 06 41				3,240	
		i	21 07 20	8				
		i	21 08 10	4 to 8				
		iL	21 08 14					
		M	21 08 58	11		38		
		F	22 05 ..					
		ePR	20 59 58					True P apparently not recorded
		iPR	{21 00 02 / .. .. 06}	5				
N		eS	21 04 20	15				
		e	21 07 35					
		i	21 10 03	11				
		iL	21 11 00	11				
		M	21 11 15		17			
		F	22 00 ..					
31		iS?	1 17 35	10				
		i	1 18 45					
W		e	1 19 47					
		e	1 19 55	15	4			
		L	1 27 08	15				
			1 31 52		3			
		F	?2 10 ..					
		i	{1 09 14 / .. .. 28}					
N		i	1 11 25					
		i	1 13 19					
		eS?	1 17 30					
		iS?	1 17 39	8	7			iS well defined.
		L	1 20 19	11				
		F	1 58 ..					

CANADA. *Meteorological Service of Canada, Victoria.*

1924.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 6		L	?18 22 06	10				
E		M	18 26 41	10		2		
		F	18 29 11					
		L	?18 22 21	10				
N		M	18 26 51	10	1			
		F	18 28 21					
7		P	10 01 04	5				
		L	10 05 10	10				
E		M	10 08 20	20		23	2,510	
		F	10 58 00					
		P	10 01 04	5				
N		L	10 05 08	10				
		M	10 06 50	18	26		2,490	
		F	10 52 00					
9		L	10 28 12	8				
E		M	10 28 48	10		5		
		F	10 34 30					
		L	10 28 20	10				
N		M	10 28 50	10	5			
		F	10 37 00					
11		L	20 43 00	10				
E		M	20 47 00	10		2		N-S too small to measure.
		F	20 59 20					
12		L	14 17 16	20				
E		M	14 19 36	17		4		
		F	14 26 01					
		P	14 09 31	8				
		L	14 18 01	20				
N		M	14 19 15	18	7		7,010	
		F	14 26 01					
14		P	21 01 27	8				
		S	21 10 18	12				
E		M	21 25 28	20		13	7,420	
		F	23 45 03					

CANADA. *Meteorological Service of Canada, Victoria*—Continued.

1924.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 14		P	21 01 25	8				
		S	21 10 18	12				
N		M	21 21 01	15	8		7,400	
		F	23 45 03					
16		L	22 00 02	8				
E		M	22 00 17	12		7	130?	
		F	22 13 32					
		L	21 59 59	8				
N		M	22 00 10	12	17		100?	
		F	22 15 12					
21		P	2 02 00	8				
		S	2 03 56	10				
		L	2 07 30	12				
E		M	2 13 43	12		4	1,080	
		F	3 18 48					
		P	2 02 00	8				
		L	2 07 30	12				
N		M	2 12 55	20	9			
		F	3 03 00					
25		P	6 13 11	10				
		L	6 20 36	20				
E		M	6 24 43	15		8		
		F	7 36 31					
		P	6 13 11	8				
N		L	6 22 50	20				
		M	6 25 35	18	14			
		F	7 36 00					
26		P	2 25 24	5				E-W component, shutter remained closed.
		L	2 37 25	20				
N		M	2 44 50	18	2		1,130	
		F	2 48 20					
29		P	2 07 49	8				
		S	2 18 42	10				
		L	2 34 44	30				
E		M	2 43 19	22		27	9,890	
		F	3 30 59					
		P	2 07 49	5				
		S	2 18 39	10				
N		L	2 35 29	30				
		M	2 41 34	25	31		9,820	
		F	4 39 00					
30		L	5 25 59	20				
E		M	5 29 34	20		3		N-S not visible.
		F	5 31 59					
30		P	14 27 58	5				
		L	14 29 18	10				
E		M	14 29 41	10		3	610	
		F	14 38 38					
		P	14 28 48	5				
		L	14 29 31	10				
N		M	14 30 21	10	10		860	
		F	14 38 58					
30		L	21 19 35	8				
E		M	21 21 37	12		4		
		F	21 42 02					
		L	21 19 02	20				
N		M	21 21 00	15	23			
		F	21 46 17					
31		L	1 21 22	8				
E		M	1 21 32	12		4		
		L	1 21 22	5				
		L	1 22 57	18				
N		M	1 24 06	18	6			
		F	1 42 20					

No earthquakes were recorded during January, 1924, at the following stations:

COLORADO. *Regis College*, Denver.

Reports for January, 1924, have not yet been received from the following stations:

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.
MASSACHUSETTS. *Harvard University*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.
NEW YORK. *Cornell University*, Ithaca.

TABLE 3.—*Late Reports (Instrumental).*

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

Date		Phase	*H. m. s.*	*Sec.*	μ	μ	*Km.*	Remarks
1923. Nov. 1		e	20 15 24					Very heavy micros; e possibly S.
		L	20 16 29	9				
		e	20 21 ..					
		F?	20 40 ..					
2		e_E	21 58 56					Very heavy micros; sheet off at 0h. 20m. with quake still on.
		e_N	21 29 02					
		S_N?	21 37 23					
		eL	21 46 18	38				
		L_E	22 09 10	30				
		L_N	22 10 02	26				
		M_E	22 23 05	19	*1,100			
3		eP_E	8 42 21					
		iP_N	8 42 21					
		S	8 46 03					
		eL_E?	8 47 ..					
		L_N	8 48 55	19				
		L_E	8 49 34	16				
		F	10 *ca.*					
3		e_N?	16 44 ..					Very heavy micros; beginning uncertain.
		eL_E?	16 18 00					
		eL_N?	16 17 24					
		L_E	17 18 11	21				
		L_N	17 18 16	26				
		L_N	17 28 ..	11				
		F	17 58 ..					
4		eP_E?	0 24 22					
		eP_N?	0 24 00					Very heavy micros; difficult.
		eS?	0 37 00					
		S_ER	0 42 00					
		eL	1 01 00					
		L_E	1 03 05	28				
		L_N	1 03 25	31				
		M_E	1 07 35	25	*500			
		M_N	1 07 15	25		*800		
		F	1 55 ..					
5		e_E	21 52 31					NS bound by damper.
		eL_E	22 18 12					L_{EN} 21:18:42 to 21:25.
		L_E	22 28 35	20				
		F	23 10 ..					
8		eS_E?	0 13 35					Very heavy micros; P obscured, possibly at 0:07:00.
		iS_N	0 13 25					
		eL_N?	0 19 30					
		F	0 40 ..					
9		e_N	3 28 30					S possibly sooner; EW poorly defined.
		eS_N?	3 32 10					
		eL_N?	3 34 42					
		L_N	3 39 ..					
		L_E	3 43 ..					
		F	4 30 *ca*					
11		e	6 04 ..					
		S?	6 11 48					
		F	6 20 ..					
11		e	14 06 ..					Difficult.
		e_E	14 14 00					
		e_N	14 14 20					
		F	15 *ca* ..					
16		e	4 33 00					e possibly sooner; very heavy micros.
		S?	4 36 24					
		eL?	4 38 00					
		L_E	4 39 ..	8				
		L_N	4 40 39	8				
		F	5					
16		e	7 28 25					Very heavy micros.
		L_E	7 31 35					
		L_N	7 32 23					
		F	7 40 ..					
17		eP_N	3 03 41					
		S?	3 12 57					
		L_E	3 31 07	15				
		L_N	3 36 ..					
		F	4 10 ..					
18		L_E	9 16 39					Very heavy micros.
		L_N	9 17 32					
		F	9 40 ..					
Dec. 5		e_E?	21 06 21					Do.
		e_N?	21 06 27					
		S_N	21 18 08					
		F						Micros.
13		e	17 05 17					Very heavy micros.
		eL_N	17 10 18	14				
		L_E	17 19 08					F lost in micros.
14		e_E	10 44 46					Rest lost in heavy micros.
		e_N	10 44 49					
21		eL_N?	8 15 18					Very heavy micros.
		F						Micros.

* Trace amplitude.

CANADA. *Meteorological Service of Canada, Toronto.*

Date		Phase	*H. m. s.*	*Sec.*	μ	μ	*Km.*	Remarks
1923. Dec. 2		e_E	15 36 15					Nothing on NS.
		L_E	15 37 53	23				Sinusoidal, small amplitude of 15:41:08.
		F	Micros..					
3		L_E	8 57 15					Nothing on NS.
		L_E	9 00 23					
		F						Micros.
5		e_N	7 59 10					EW masked by wind effects; small amplitude.
		L_N	8 02 49					
		F	Micros..					
5		L	21 22 00					*East-West.*
		i	21 27 23					P and S lost, wind affecting boom.
		L	21 31 00	23				
		i	21 35 00					Japan.
		L	21 37 26	15				
		L	21 39 56					Sinusoidal.
			to 41 25	15	9			
		eS	21 17 38					*North-South.*
		i	21 17 47					
		L	21 31 12	22				Sinusoidal.
			to 34 30			13		
		L	21 40 30	15				
		i	22 02 38	15				
		F						Micros.
5		e	23 48 30					*North-South.*
		e	23 56 32					Preceded by micros.
		e	23 57 00					Irregular waves.
6		e	0 54 33					EW affected by winds and micros.
		e	1 11 41					
		F	?1 28 00					
7		e	16 31 58					Small amplitude.
		e	16 34 15					*East-West.*
		F						Micros.
		e	16 30 23					*North-South.*
		e	16 32 13					Small amplitude.
		F						Micros.
11		eL	6 11 05	23				*East-West.*
		L	6 14 38	23				
		L	6 18 00					Uniform.
		L	6 22 08	23				Do.
			to 26 15					F in micros.
		e	6 10 00					*North-South.*
		L	6 12 26					Very small amplitude.
			to 18 00					
		L	6 21 00					
		F						Micros.
12		L	11 21 15					*North-South.*
		L	11 21 37					Slow waves; may not be seismic.
		L	11 28 30					
		F	11 40 ..					
		L_E	11 31 08					Micros and wind mask phases.
		F_E	?					
13		e	17 09 52					*East-West.*
		L	17 10 08	17	7			
			to 13 33	15				Sinusoidal.
		L	17 14 15					Irregular.
		F						Micros.
		L	17 10 ..	19				*North-South.*
		L	17 10 32	13				Sinusoidal.
			to 13 15					
		M	17 10 40			7		
		F	17 29 ..					
15		L?	12 50 40					*East-West.*
		L	12 51 57					Irregular. Masked by wind and micros.
		F	Micros ..					
		i	12 48 40					*North-South.*
		L	12 50 15	10				Small uniform waves.
			to 53 ..					
		F						Micros.
16		e	7 51 08					*East-West.*
		L	7 58 00					Irregular. Small amplitude.
		F	Micros..					
		e	7 45 15					Micros; readings doubtful.
		i	7 58 23					
		L	8 02 15					
		F	8 27 00					
22		P	?10 04 51					Micros.
			or 05 23				3,120	Ecuador?
		iS	10 09 43	5–8				*East-West.*
		eL	10 12 23	15				
		i	10 13 24					
		i	10 16 28	8				
		L	10 17 41	14				
		L	10 17 57	30				
		L	10 20 51					
			to 22 00					

TABLE 3.—*Late Reports (Instrumental)*—Continued.

CANADA. *Meteorological Service of Canada, Toronto*—Continued.

1923.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 22	......	M1....	10 21 11	......	......	......	......	
		M2....	10 21 28	......	23	......	......	
		L.....	10 22 15	17	......	......	......	
		F.....	11 24 00	......	......	......	......	
		P?....	10 04 47	......	......	......	3,110	*North-South.*
		S.....	10 09 40	5	......	......	......	Micros.
		e.....	10 16 14	......	......	......	......	
		L.....	10 16 30	......	......	......	......	
		L.....	10 16 51	25	......	......	......	
		L.....	*10* 20 15	19	......	......	......	Uniform.
			to 22 38	19	......	......	......	
		M1....	10 21 24	23	......	21	......	
		M2....	10 21 41	......	......	......	......	
		L.....	10 23 38	15	......	......	......	
		F.....	11 24 00	......	......	......	......	
22	......	e_E....	18 13 15	......	......	......	......	Very small; NS. barely noticeable.
		e_E....	18 14 30	23	......	......	......	
		e_E....	18 16 15	......	......	......	......	
		F_E....	18 26 00	......	......	......	......	
26	......	e_E....	?3 09 33	......	......	......	......	Micros; NS. masked.

CANADA. *Meteorological Service of Canada, Toronto*—Continued.

1923.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 26	......	L_E....	3 11 14	......	......	......	......	F in micros.
27	......	i.....	15 03 08	......	......	......	......	*East-West.*
		e.....	15 03 38	......	......	......	......	
		i.....	15 06 30	......	......	......	......	Paperchanged 15:20.
		i.....	15 02 45	......	......	......	......	*North-South;* minute micros.
		i.....	15 06 38					
28	......	e_N....	18 11 23	......	......	......	......	EW. masked by wind.
		L_N....	18 15 35	......	......	......	......	F in micros.
28	......	L_E....	23 14 45	......	......	......	......	Masked by wind and micros: sinusoidal waves.
			to 17 00	23	9	......	......	
		e_N....	22 56 32	......	......	......	......	
		L_N....	23 02 08	......	......	......	......	Small amplitude.
		L_N....	23 19 19	......	......	......	......	
		L.....	23 25 38	......	......	......	......	F in micros.

Chart I. Tracks of Centers of Anticyclones, January, 1924. (Inset) Departure of Monthly Mean Pressure from Normal.
(Plotted by Wilfred P. Day.)

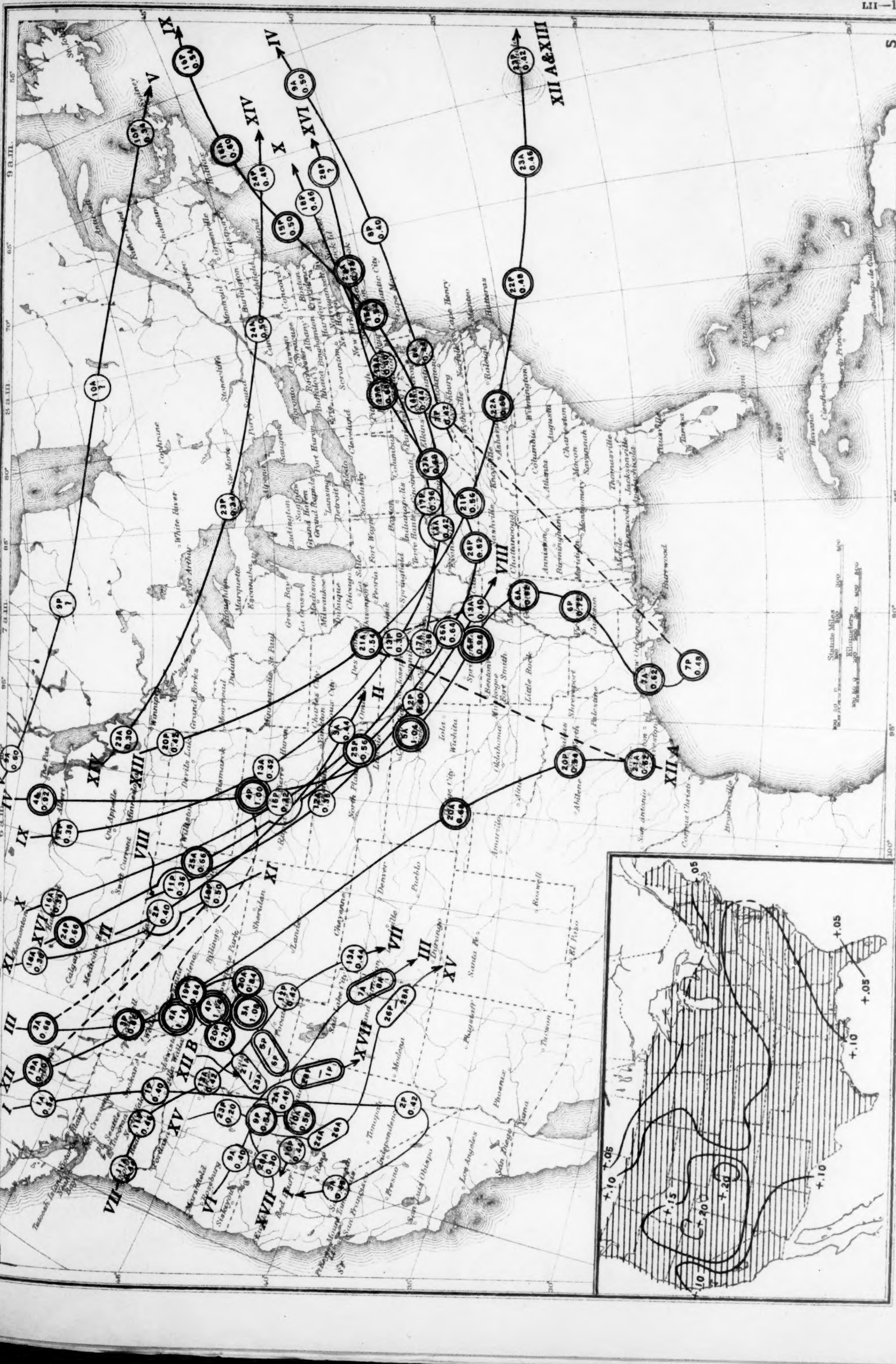

Chart I. Tracks of Centers of Anticyclones, January, 1924. (Inset) Departure of Monthly Mean Pressure from Normal.
(Plotted by Wilfred P. Day.)

Chart II. Tracks of Centers of Cyclones, January, 1924. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)

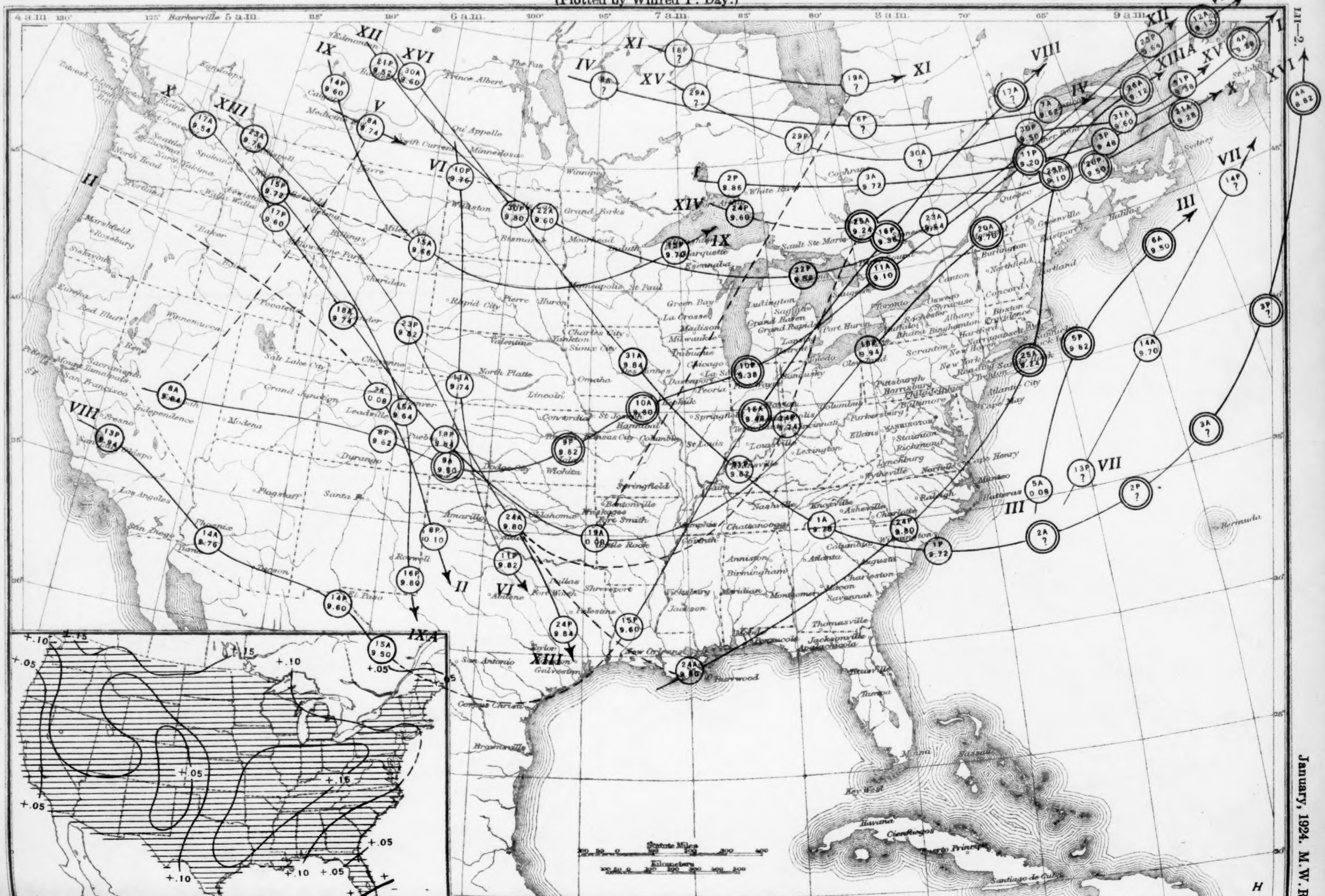

Chart III. Departure (°F.) of the Mean Temperature from the Normal, January, 1924.

Chart III. Departure (°F.) of the Mean Temperature from the Normal, January, 1924.

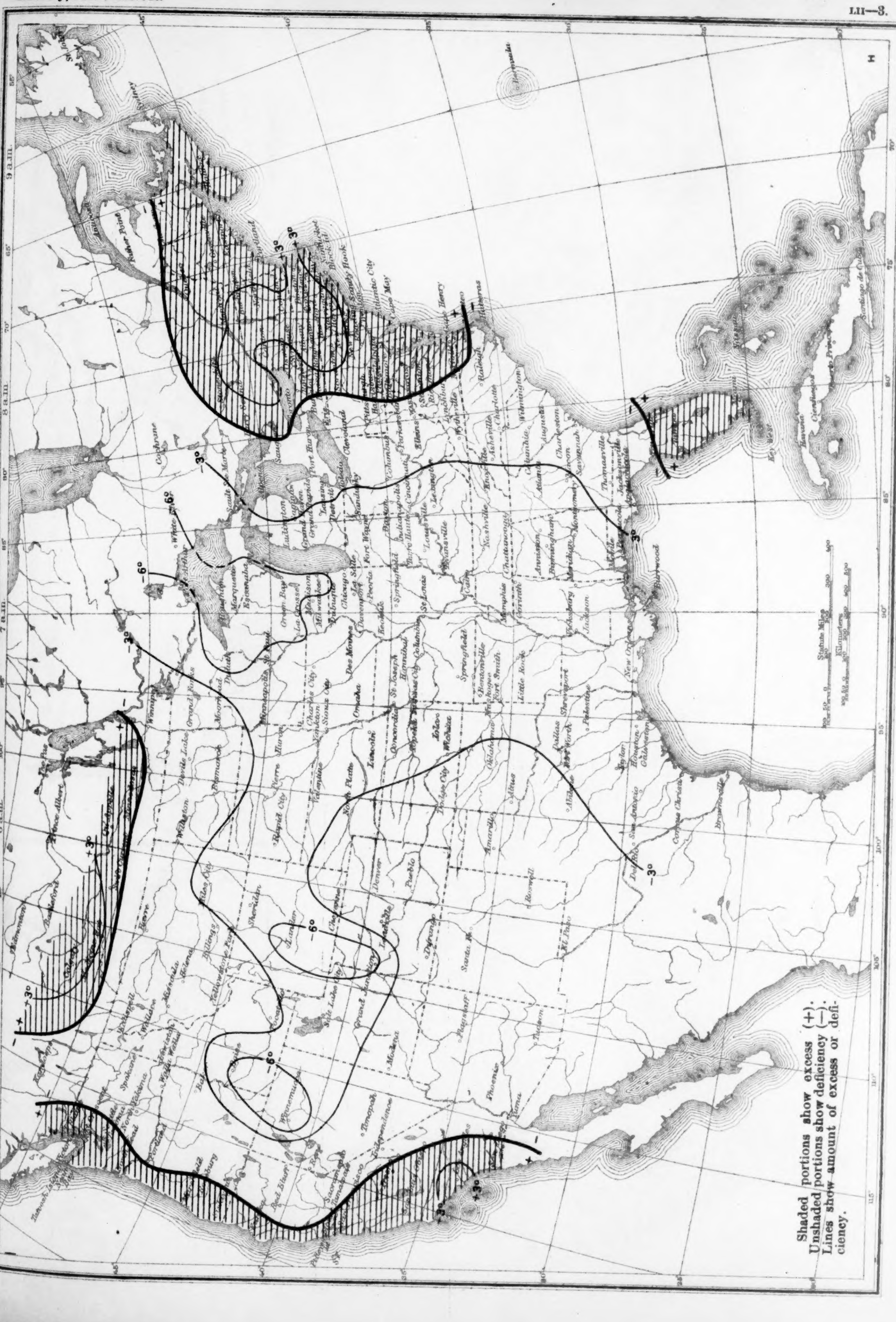

Chart IV. Total Precipitation, Inches, January, 1924. (Inset) Departure of Precipitation from Normal.

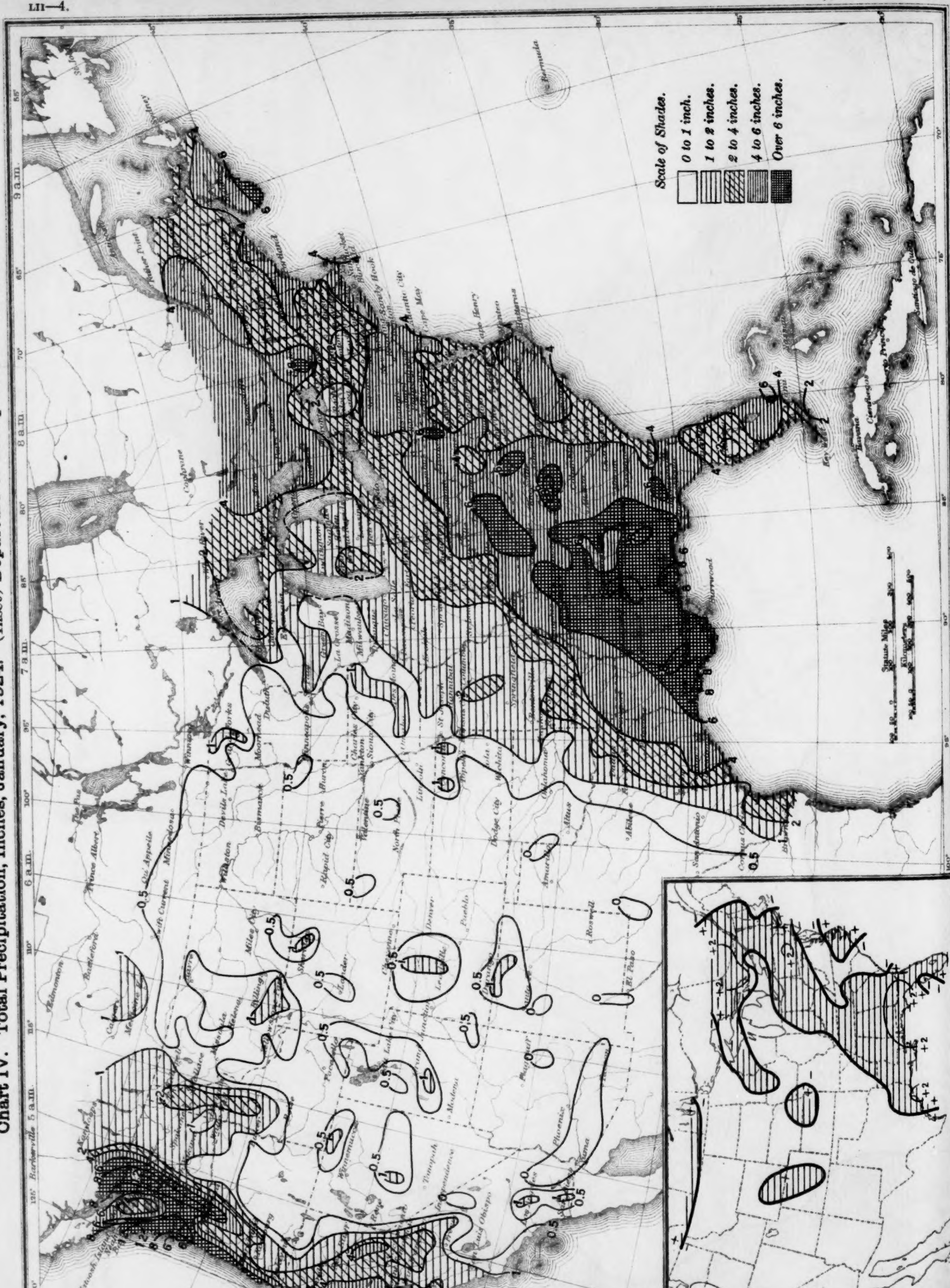

Chart V. Percentage of Clear Sky between Sunrise and Sunset, January, 1924.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, January, 1924.

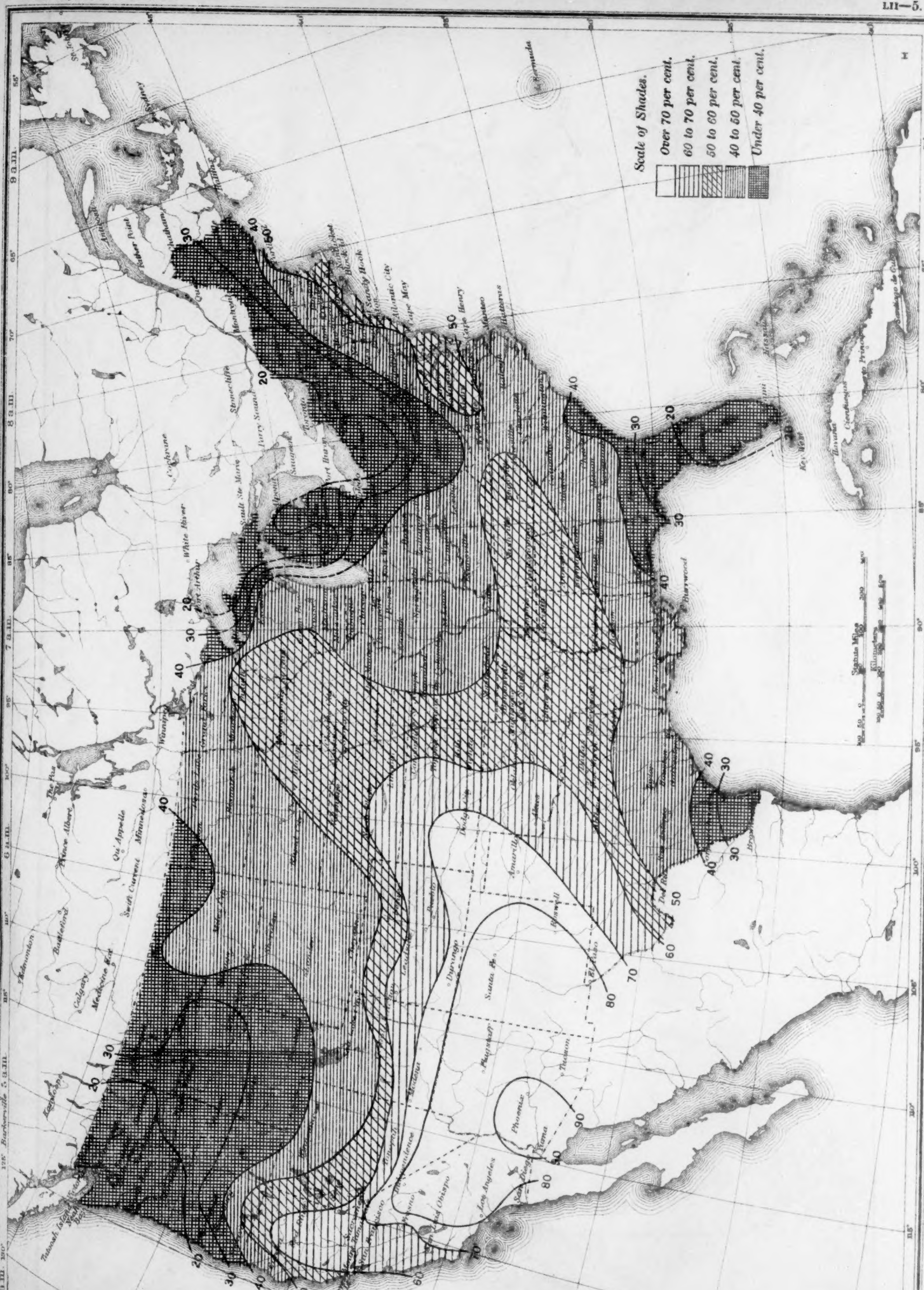

Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, January, 1924.

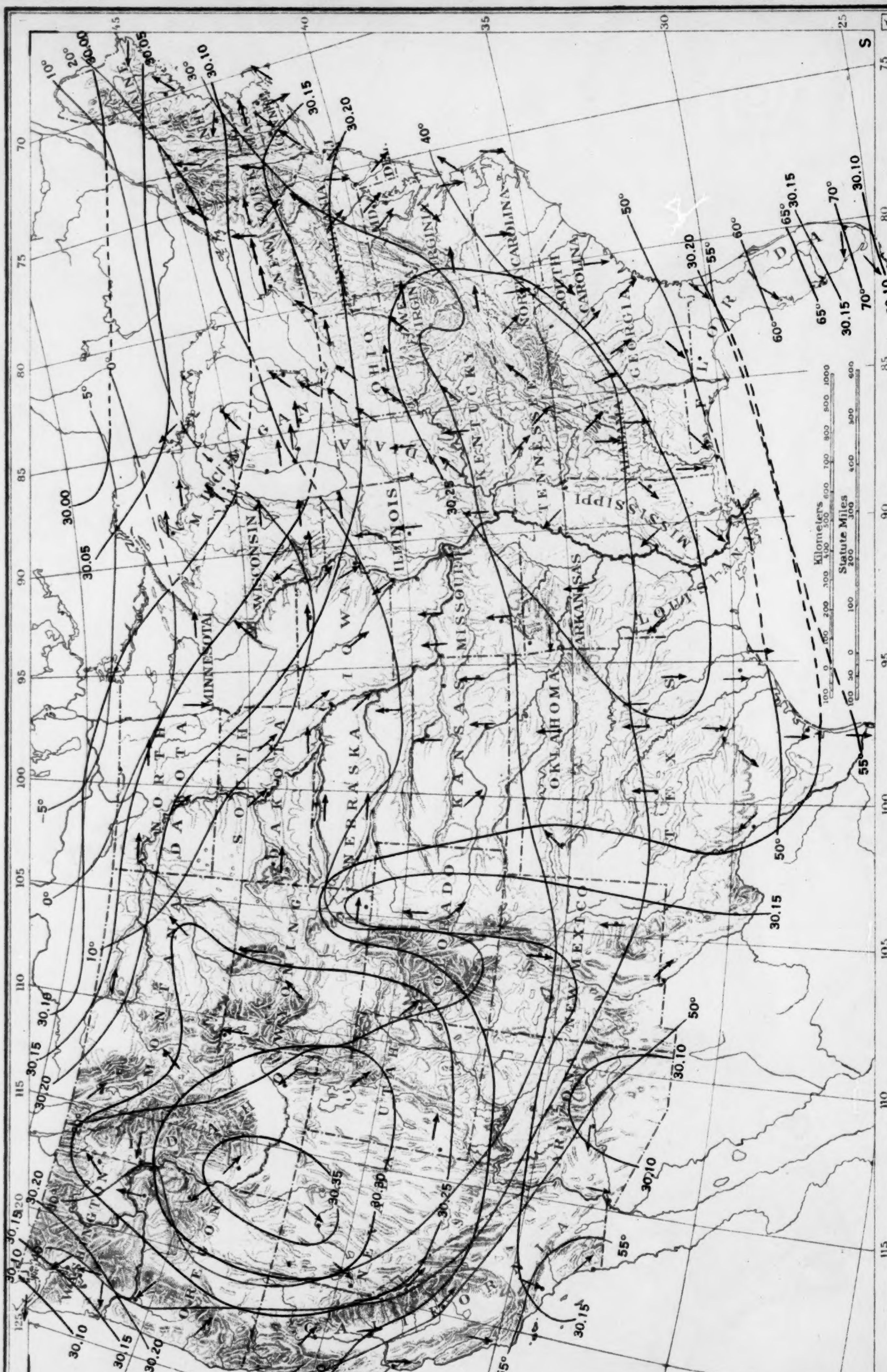

Chart VII. Total Snowfall, Inches, January, 1924. (Inset) Depth of Snow on Ground at end of Month.

Chart VII. Total Snowfall, Inches, January, 1924. (Inset) Depth of Snow on Ground at end of Month.

Chart VIII. Weather Map of North Atlantic Ocean, January 5, 1924.
(Plotted by F. A. Young.)

Chart VIII. Weather Map of North Atlantic Ocean, January 5, 1924.
(Plotted by F. A. Young.)

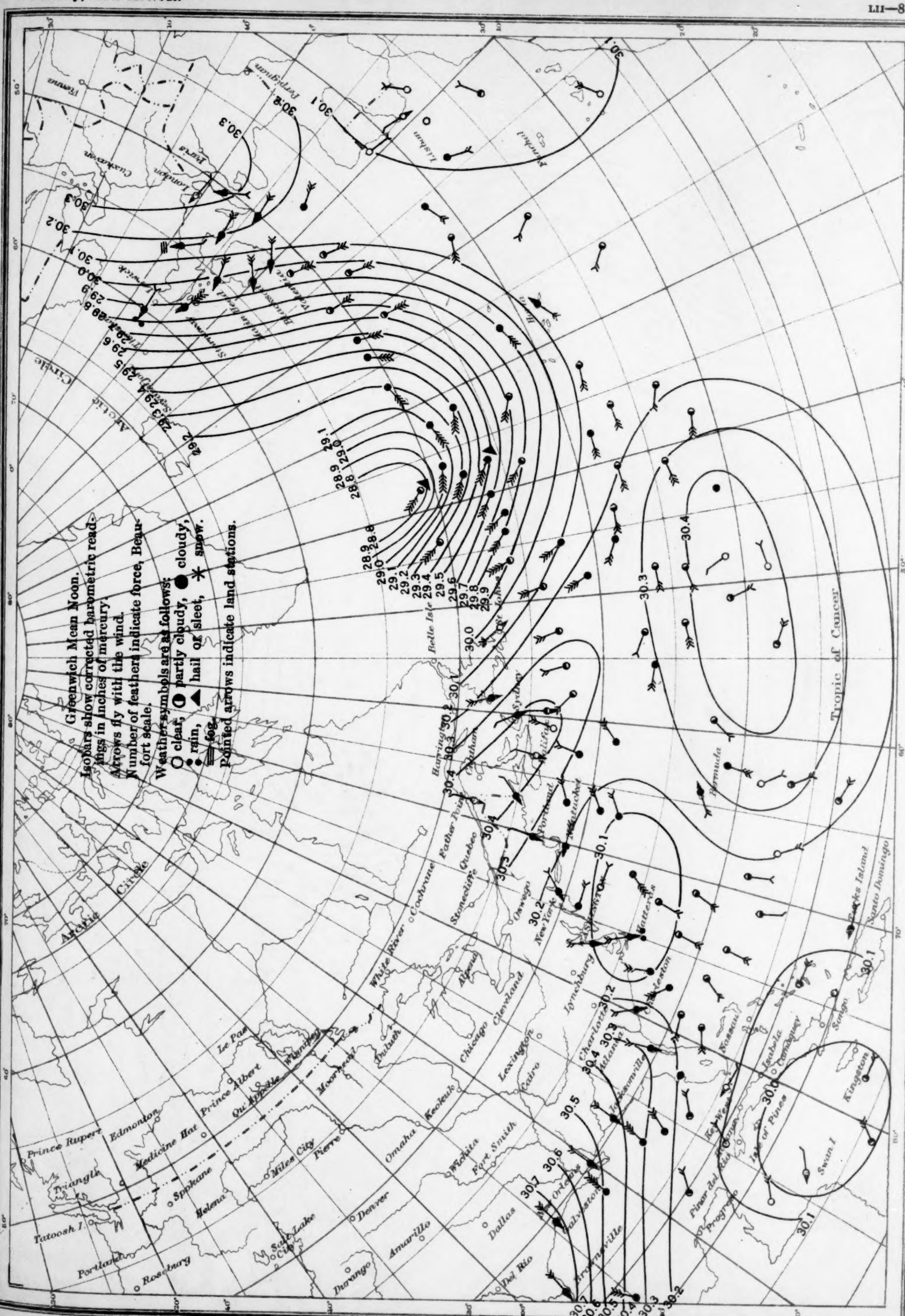

Chart IX. Weather Map of North Atlantic Ocean, January 6, 1924.

(Plotted by F. A. Young.)

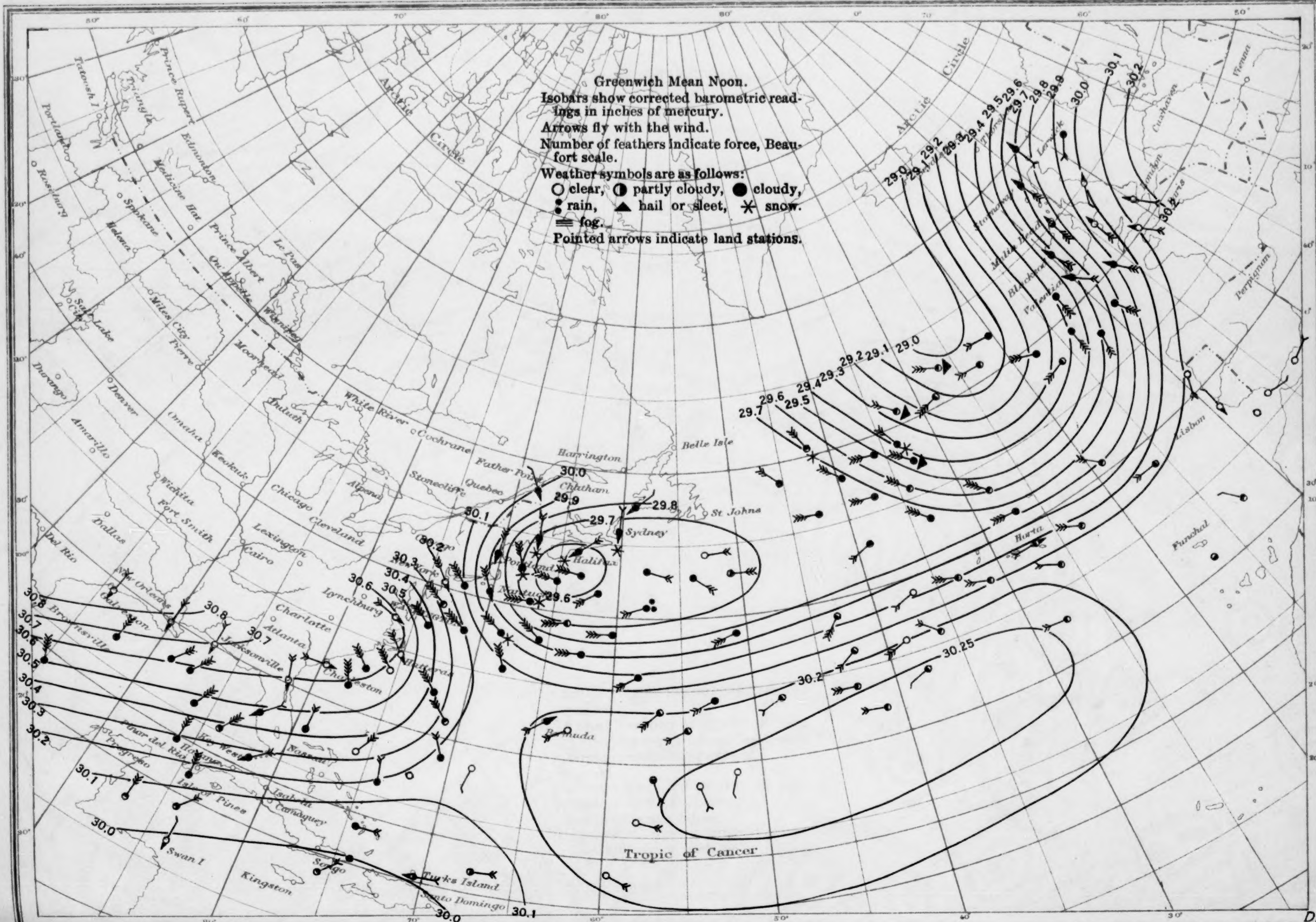

Chart X. Weather Map of North Atlantic Ocean, January 7, 1924.

(Plotted by F. A. Young.)

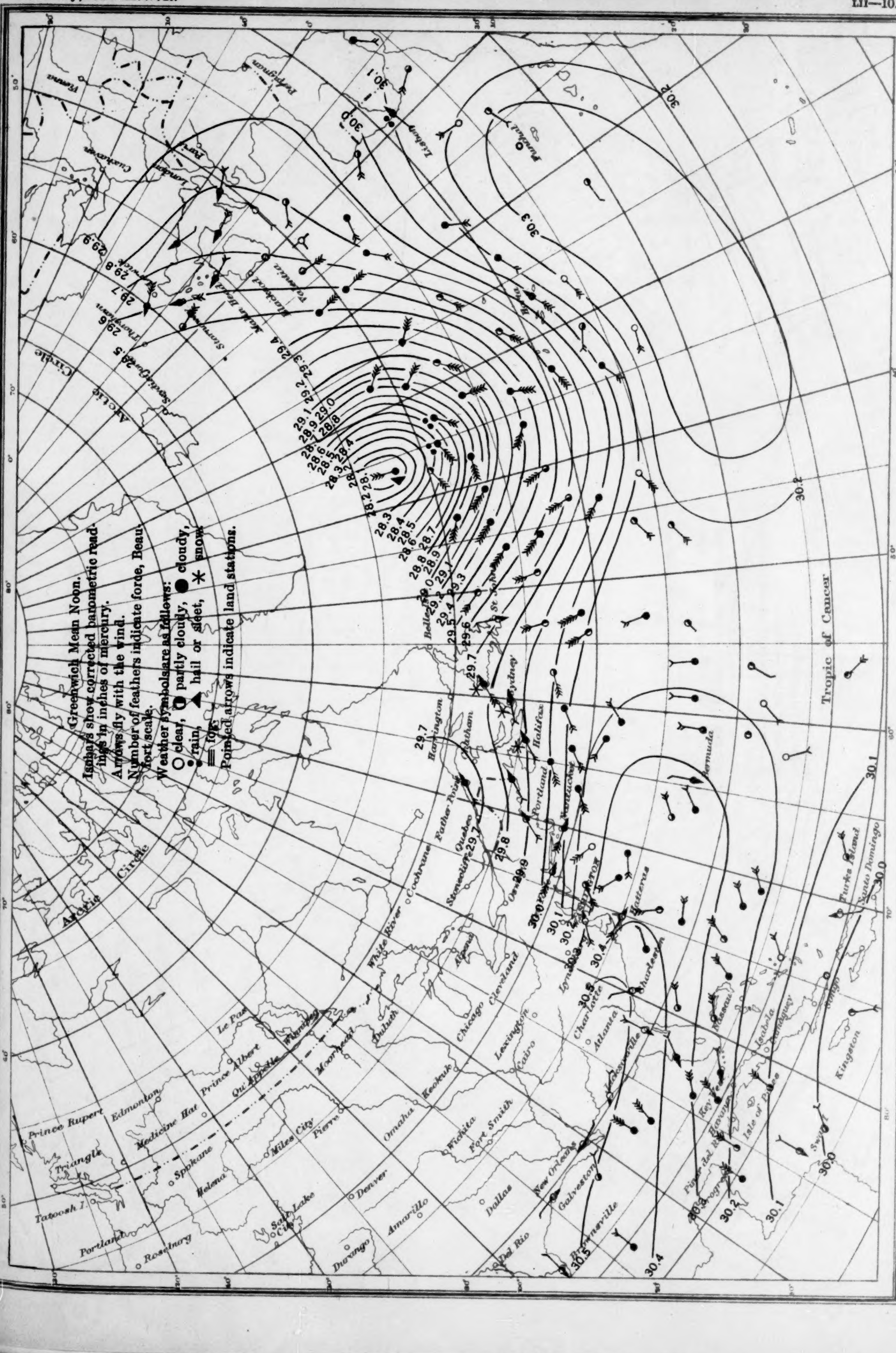

Chart X. Weather Map of North Atlantic Ocean, January 7, 1924.
(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, January 8, 1924.
(Plotted by F. A. Young.)